AD-A101 217 ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND WS--ETC F/G 17/7
HIGH FREQUENCY POSITION LOCATION: AN ASSESSMENT OF LIMITATIONS --ETC(U)
MAY 81 M G HEAPS, D W HOOCK, R O OLSEN

UNCLASSIFIED ERADCOM/ASL-TR-0088 NL

1 OF 1
AD
A101 217

END
DATE
FILMED
8-81
DTIC

DEPARTMENT OF THE ARMY

ASL-TR-0088

AD

Reports Control Symbol
OSD - 1366

ADA101217

HIGH FREQUENCY POSITION LOCATION: AN ASSESSMENT OF LIMITATIONS AND POTENTIAL IMPROVEMENTS

MAY 1981

By

MELVIN G. HEAPS

DONALD W. HOOCK

ROBERT O. OLSEN

BERNARD F. ENGEBOS

ROBERTO RUBIO

Approved for public release; distribution unlimited

US Army Electronics Research and Development Command
ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, NM 88002

81 7 10 054

ASL-TR-0088

AD

Reports Control Symbol
OSD - 1366

HIGH FREQUENCY POSITION LOCATION: AN ASSESSMENT OF LIMITATIONS AND POTENTIAL IMPROVEMENTS

MAY 1981

By

MELVIN G. HEAPS

DONALD W. HOOCK

ROBERT O. OLSEN

BERNARD F. ENGEBOS

ROBERTO RUBIO

Approved for public release; distribution unlimited

US Army Electronics Research and Development Command
ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, NM 88002

NOTICES

Disclaimers

Disposition

NOTICES

Disclaimers

Disposition

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ASL-TR-0088	AD-A101 217	

4. TITLE (and Subtitle)
HIGH FREQUENCY POSITION LOCATION: AN ASSESSMENT OF LIMITATIONS AND POTENTIAL IMPROVEMENTS

5. TYPE OF REPORT & PERIOD COVERED
Final Report

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Melvin G. Heaps, Donald W. Hoock, Robert O. Olsen, Bernard F. Engebos, and Roberto Rubio

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
US Army Atmospheric Sciences Laboratory
White Sands Missile Range, NM 88002

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
DA Task 1L161102B53A

11. CONTROLLING OFFICE NAME AND ADDRESS
US Army Electronics Research and Development Command, Adelphi, MD 20783

12. REPORT DATE
May 1981

13. NUMBER OF PAGES
18

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

High frequency
Direction finding
Position location
Ionospheric irregularity
Ionospheric variability
Single source locator

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The general problems of using high frequency direction finding techniques as an accurate means of surveillance and position location are assessed. The primary emphasis is on determining the range errors associated with a single site locator by using the intercepted sky wave. Current errors in position locations are on the order of 20 km due to ionospheric variability, antenna size limitations, and data acquisition and processing problems. Improvements in position location accuracies to the order of 1 km will require complementary use of the direct wave and/or the ground wave.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ACKNOWLEDGMENT

The authors acknowledge the many helpful conversations with personnel from several US Army activities such as the Electronic Warfare Laboratory, the Signals Warfare Laboratory, and the Signal and Intelligence School. A debt of gratitude is also owed for help and advice rendered by individuals from the Radiolocation Research Laboratory at the University of Illinois, the Southwest Research Institute, the Remote Measurements Laboratory at SRI International, and Technology for Communications International.

ACKNOWLEDGMENT

The authors acknowledge the many helpful conversations with personnel from several US Army activities such as the Electronic Warfare Laboratory, the Signals Warfare Laboratory, and the Signal and Intelligence School. A debt of gratitude is also owed for help and advice rendered by individuals from the Radiolocation Research Laboratory at the University of Illinois, the Southwest Research Institute, the Remote Measurements Laboratory at SRI International, and Technology for Communications International.

SUMMARY

This report addresses the question of using high frequency (HF) radio wave direction finding (DF) techniques as an accurate means of surveillance and position location on the modern battlefield. The desired accuracy in position would be on the order of 0.1 km for tactical applications.

The initial concept explored is that of a single site locator (SSL), 100 to 200 km to the rear of the battle area, which would sense HF emitting targets at approximately the same distances on the other side of the battle area. Currently, state-of-the-art techniques have errors on the order of 20 km in position location. The main sources of error can be grouped into the following areas:

- ionospheric variability and irregularity;

- antenna and system size limitations; and

- data acquisition, processing, and interpretation.

The prognosis on improvement of SSL range accuracies is that errors in position location can be reduced to 5 to 10 km by incorporating the real-time ionosphere variability into ray retracing calculations and through improved sophistication in software for data acquisition and interpretation. The basic limitation is the use of a radio wave path which employs the ionosphere as a reflecting medium. The possibility of employing several SSL systems to form a larger net may yield uncertainties of only 5 km or slightly less. However, the basic limitations due to the ionosphere remain, and accuracies smaller than a few kilometers cannot be attained in the foreseeable future.

The ultimate goal of achieving HF position location accuracies on the order of 0.1 km may possibly be attained if the approach to the solution is altered. This alternative would involve a two-tier method. The first tier would be the use of the type of SSL discussed above for surveillance and location of the desired targets to within accuracies of 5 to 10 km, and the second tier would be the use of mobile units relying on either the ground wave or direct wave to triangulate on the desired target. This alternative approach implies several changes in philosophy. First, by using a mode of HF propagation other than the sky wave, the effective range of detection has been reduced to less than 100 km and often to less than 30 km. Second, the use of the ground wave implies that two or three mobile units shall be deployed in or very near the battle area. This alternate approach, while offering potential increases in position location accuracy, obviously involves noncomplementary trade-offs in effective range of the mobile units, number of sites involved, and coordination of efforts.

SUMMARY

This report addresses the question of using high frequency (HF) radio wave direction finding (DF) techniques as an accurate means of surveillance and position location on the modern battlefield. The desired accuracy in position would be on the order of 0.1 km for tactical applications.

The initial concept explored is that of a single site locator (SSL), 100 to 200 km to the rear of the battle area, which would sense HF emitting targets at approximately the same distances on the other side of the battle area. Currently, state-of-the-art techniques have errors on the order of 20 km in position location. The main sources of error can be grouped into the following areas:

- ionospheric variability and irregularity;

- antenna and system size limitations; and

- data acquisition, processing, and interpretation.

The prognosis on improvement of SSL range accuracies is that errors in position location can be reduced to 5 to 10 km by incorporating the real-time ionosphere variability into ray retracing calculations and through improved sophistication in software for data acquisition and interpretation. The basic limitation is the use of a radio wave path which employs the ionosphere as a reflecting medium. The possibility of employing several SSL systems to form a larger net may yield uncertainties of only 5 km or slightly less. However, the basic limitations due to the ionosphere remain, and accuracies smaller than a few kilometers cannot be attained in the foreseeable future.

The ultimate goal of achieving HF position location accuracies on the order of 0.1 km may possibly be attained if the approach to the solution is altered. This alternative would involve a two-tier method. The first tier would be the use of the type of SSL discussed above for surveillance and location of the desired targets to within accuracies of 5 to 10 km, and the second tier would be the use of mobile units relying on either the ground wave or direct wave to triangulate on the desired target. This alternative approach implies several changes in philosophy. First, by using a mode of HF propagation other than the sky wave, the effective range of detection has been reduced to less than 100 km and often to less than 30 km. Second, the use of the ground wave implies that two or three mobile units shall be deployed in or very near the battle area. This alternate approach, while offering potential increases in position location accuracy, obviously involves noncomplementary trade-offs in effective range of the mobile units, number of sites involved, and coordination of efforts.

TABLE OF CONTENTS

TABLE OF CONTENTS

1. INTRODUCTION

For more than 40 years the standard link for communication between two widely separated points has been the use of the high frequency (HF) band of the radio wave spectrum. The widespread use of HF communications is due to several factors: the technology is well-known and relatively simple, the equipment is easy to manufacture and deploy, and the cost is much less than technologically more sophisticated systems involving microwaves or satellites.

Within the defense community there has been renewed interest in HF communications which stems from rekindled awareness of HF as an important backup or even primary link in our defense communications system. In addition, the knowledge that Soviet forces depend heavily on HF communication leads to the question of how best to exploit this dependence on HF to our tactical advantage. This report concentrates mainly on this latter question, sketches the state-of-the-art accuracies in HF direction finding and position location (commonly referred to as HF-DF), and outlines two programs for improving these accuracies in HF position location.

2. BASIC CONSIDERATIONS AND PHYSICAL LIMITATIONS

HF position location by use of a single site locator (SSL) involves not only receiving or intercepting a signal from a transmitter, but also receiving the signal in such a way that two angles of arrival and a distance parameter can be determined. The azimuthal angle, like the angle of a compass, gives the direction from which the signal comes. Figure 1 illustrates the elevation angle and a parameter, usually the height of the reflecting layer of the

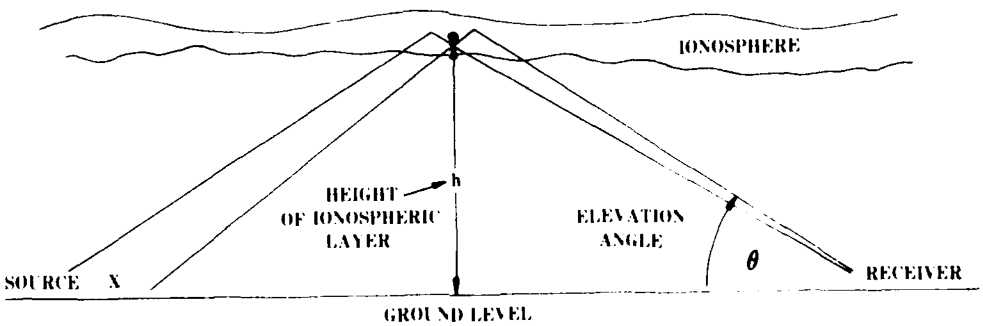

Figure 1. The elevation angle, θ, and the ionospheric height, h, used to determine the range of the emitting source.

ionosphere, from which the distance (range) to the transmitter is determined. However, any emitting HF source yields two types of waves, one which propagates along the earth-air interface (the ground wave) and the other which propagates through the atmosphere (the direct wave) eventually to be reflected off the ionosphere (the sky wave). The proportion between the two waves for any given transmitter depends on antenna design and orientation. Generally speaking, when one is close to the source, about 50 km or less, the

1. INTRODUCTION

For more than 40 years the standard link for communication between two widely separated points has been the use of the high frequency (HF) band of the radio wave spectrum. The widespread use of HF communications is due to several factors: the technology is well-known and relatively simple, the equipment is easy to manufacture and deploy, and the cost is much less than technologically more sophisticated systems involving microwaves or satellites.

Within the defense community there has been renewed interest in HF communications which stems from rekindled awareness of HF as an important backup or even primary link in our defense communications system. In addition, the knowledge that Soviet forces depend heavily on HF communication leads to the question of how best to exploit this dependence on HF to our tactical advantage. This report concentrates mainly on this latter question, sketches the state-of-the-art accuracies in HF direction finding and position location (commonly referred to as HF-DF), and outlines two programs for improving these accuracies in HF position location.

2. BASIC CONSIDERATIONS AND PHYSICAL LIMITATIONS

HF position location by use of a single site locator (SSL) involves not only receiving or intercepting a signal from a transmitter, but also receiving the signal in such a way that two angles of arrival and a distance parameter can be determined. The azimuthal angle, like the angle of a compass, gives the direction from which the signal comes. Figure 1 illustrates the elevation angle and a parameter, usually the height of the reflecting layer of the

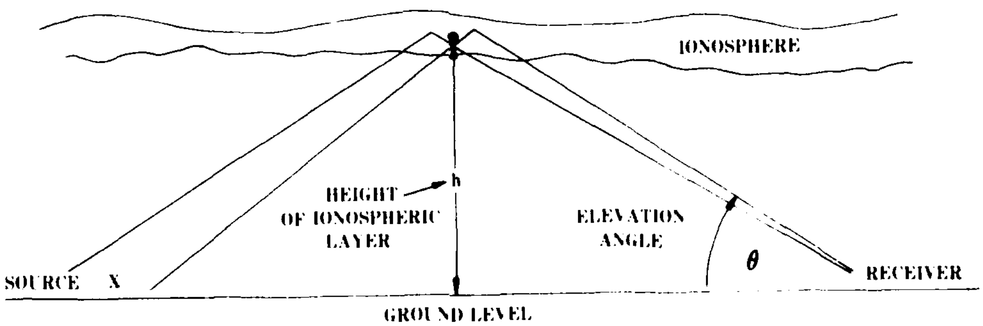

Figure 1. The elevation angle, θ, and the ionospheric height, h, used to determine the range of the emitting source.

ionosphere, from which the distance (range) to the transmitter is determined. However, any emitting HF source yields two types of waves, one which propagates along the earth-air interface (the ground wave) and the other which propagates through the atmosphere (the direct wave) eventually to be reflected off the ionosphere (the sky wave). The proportion between the two waves for any given transmitter depends on antenna design and orientation. Generally speaking, when one is close to the source, about 50 km or less, the

ground wave is the strongest signal received--although the distance could be as small as 20 km or as large as 100 km depending on the topography, soil type, and soil conductivity. In this region the reflected sky wave is of near vertical incidence and yields little useful information on direction or range. Thus for "close-quarters" HF-DF, a system which utilizes the ground wave would be the most applicable. In the region roughly 50 to 100 km from the source (again these limits are only approximate), both the ground wave and the sky wave can be received (with the subsequent interference problem), but with the constraint that the ground wave is fading out while the sky wave still has a large angle of vertical incidence, so that little useful DF information can be obtained from a ground-based HF-DF system. In this region a useful HF-DF system would be on an airborne platform, above the ground wave and suitably shielded from the sky wave, which would utilize the directly incident HF wave. At ranges of greater than 100 km, and most optimally at ranges of a few hundreds of kilometers, the "conventional" ground-based HF-DF system using the sky wave should be employed. Figure 2 shows a schematic of these options.

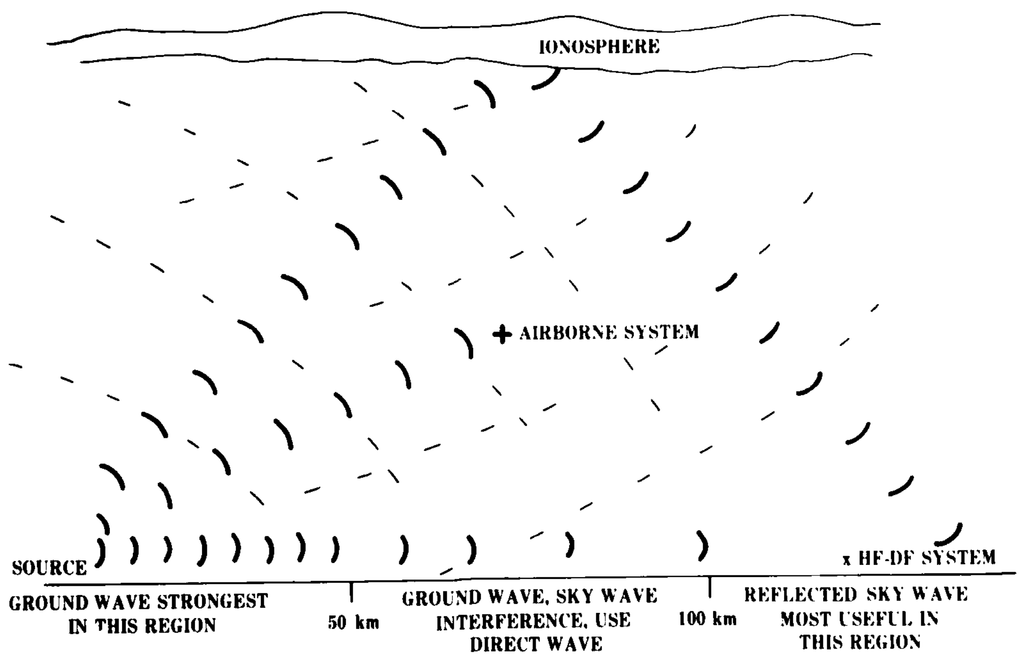

Figure 2. Schematic of options.

ground wave is the strongest signal received--although the distance could be as small as 20 km or as large as 100 km depending on the topography, soil type, and soil conductivity. In this region the reflected sky wave is of near vertical incidence and yields little useful information on direction or range. Thus for "close-quarters" HF-DF, a system which utilizes the ground wave would be the most applicable. In the region roughly 50 to 100 km from the source (again these limits are only approximate), both the ground wave and the sky wave can be received (with the subsequent interference problem), but with the constraint that the ground wave is fading out while the sky wave still has a large angle of vertical incidence, so that little useful DF information can be obtained from a ground-based HF-DF system. In this region a useful HF-DF system would be on an airborne platform, above the ground wave and suitably shielded from the sky wave, which would utilize the directly incident HF wave. At ranges of greater than 100 km, and most optimally at ranges of a few hundreds of kilometers, the "conventional" ground-based HF-DF system using the sky wave should be employed. Figure 2 shows a schematic of these options.

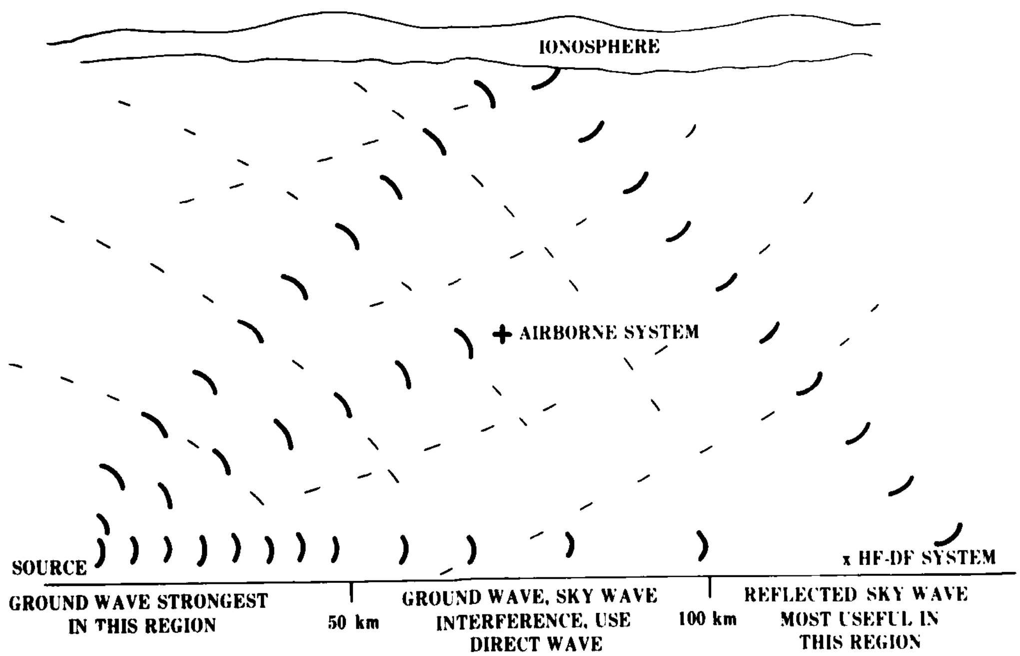

Figure 2. Schematic of options.

Several limitations and uncertainties now arise. These limitations and uncertainties may be grouped into three categories. The first category deals with the ionospheric variability and irregularity which must be considered. The second category concerns the physical size and alignment of the antenna system one desires to field. The last category includes the problems of data acquisition, processing, and interpretation.

The first category of limitations concerns the ionospheric variability and irregularity which interfere with an accurate determination of the true direction of arrival of the incident HF signal. Ideally the ionosphere should be a perfectly smooth reflecting medium at a fixed height above the surface of the earth for all points. In practice there are many effects which must be accounted for. The height of the ionospheric reflective layer, which is itself a function of frequency of the radio wave, varies in time. This type of variation may occur at any time, but is especially noticeable at sunrise and sunset. The ionosphere may also be tilted a few degrees; that is, planes of constant electron density are not precisely parallel to the earth. Again such tilts are prevalent in the day/night transition zone. Traveling ionospheric disturbances (TID) also cause variations in height and tilt which are not directly relatable to solar influence. Actually there is an entire spectrum of waves or irregularities in the ionosphere--from TID with wavelengths on the order of 1000 km and periods of tens of minutes down to waves of a few kilometers or less in size and variations of a few seconds. These factors tend to make the reflective layer look rather corrugated and specular. Many ionospheric variations have been successfully incorporated into the determination of radio propagation paths, but of necessity such techniques can include only the large-scale, regular ionospheric variations. A basic constraint for attaining small HF position location errors is the inclusion of the real-time ionospheric behavior into the ray retracing programs; this behavior is now being included in some systems. Vertical ionospheric soundings can yield the real-time ionospheric heights overhead, and oblique soundings from transmitters not colocated with the receiver (which is presumably at the HF position location site) can yield additional information on tilts and some TID. The basic limitation is that this information is most likely not for the section of the ionosphere from which the desired HF intercept is being reflected. Thus, the conditions observed overhead or obliquely must be extrapolated to the desired point of reflection. This procedure is an improvement, but it still leaves room for error.

The commonly used HF band runs from 2 to 30 MHz, which corresponds to wavelengths ranging from 150 m down to 10 m. Much of the HF communication traffic is carried on the lower frequency, that is, longer wavelength, end of the band. To accurately determine the angle of arrival, the "antenna" should be at least as large as the wavelength of the signal being received--in practice several small dipoles or similarly designed antennas are linked together to form a larger array of the requisite size. Thus, one is faced with a basic constraint: the antenna system must be at least 100 to 200 m in size. Larger arrays will buy increased accuracy but create increased deployment problems. Smaller sized systems will simply not produce sufficient angular resolution.

The third major category of limitations lies in the area of data acquisition, processing, and interpretation. Several problems arise due to limitations

Several limitations and uncertainties now arise. These limitations and uncertainties may be grouped into three categories. The first category deals with the ionospheric variability and irregularity which must be considered. The second category concerns the physical size and alignment of the antenna system one desires to field. The last category includes the problems of data acquisition, processing, and interpretation.

The first category of limitations concerns the ionospheric variability and irregularity which interfere with an accurate determination of the true direction of arrival of the incident HF signal. Ideally the ionosphere should be a perfectly smooth reflecting medium at a fixed height above the surface of the earth for all points. In practice there are many effects which must be accounted for. The height of the ionospheric reflective layer, which is itself a function of frequency of the radio wave, varies in time. This type of variation may occur at any time, but is especially noticeable at sunrise and sunset. The ionosphere may also be tilted a few degrees; that is, planes of constant electron density are not precisely parallel to the earth. Again such tilts are prevalent in the day/night transition zone. Traveling ionospheric disturbances (TID) also cause variations in height and tilt which are not directly relatable to solar influence. Actually there is an entire spectrum of waves or irregularities in the ionosphere--from TID with wavelengths on the order of 1000 km and periods of tens of minutes down to waves of a few kilometers or less in size and variations of a few seconds. These factors tend to make the reflective layer look rather corrugated and specular. Many ionospheric variations have been successfully incorporated into the determination of radio propagation paths, but of necessity such techniques can include only the large-scale, regular ionospheric variations. A basic constraint for attaining small HF position location errors is the inclusion of the real-time ionospheric behavior into the ray retracing programs; this behavior is now being included in some systems. Vertical ionospheric soundings can yield the real-time ionospheric heights overhead, and oblique soundings from transmitters not colocated with the receiver (which is presumably at the HF position location site) can yield additional information on tilts and some TID. The basic limitation is that this information is most likely not for the section of the ionosphere from which the desired HF intercept is being reflected. Thus, the conditions observed overhead or obliquely must be extrapolated to the desired point of reflection. This procedure is an improvement, but it still leaves room for error.

The commonly used HF band runs from 2 to 30 MHz, which corresponds to wavelengths ranging from 150 m down to 10 m. Much of the HF communication traffic is carried on the lower frequency, that is, longer wavelength, end of the band. To accurately determine the angle of arrival, the "antenna" should be at least as large as the wavelength of the signal being received--in practice several small dipoles or similarly designed antennas are linked together to form a larger array of the requisite size. Thus, one is faced with a basic constraint: the antenna system must be at least 100 to 200 m in size. Larger arrays will buy increased accuracy but create increased deployment problems. Smaller sized systems will simply not produce sufficient angular resolution.

The third major category of limitations lies in the area of data acquisition, processing, and interpretation. Several problems arise due to limitations

mentioned in the above categories. Resolution of the angles of arrival due to the limitations in antenna size implies that the reported value will tend to wander. Fading (even loss) of the signal can occur due to increased ionospheric absorption and several types of signal interference mechanisms. Multipath propagation of signals can cause problems in selection of the correct ionospheric parameters for the matching path and can also introduce interference fading. Co-channel interference involves the reception of unwanted, spurious signals and creates subsequent problems in signal discrimination. Also interference between the ordinary and extraordinary waves of the same signal can occur. Many of these problems have been mitigated in recent years through increasing use of computerized data handling and sophisticated software routines for signal processing and interpretation. To maintain and to improve these advances, a basic requirement would be the inclusion of a sophisticated minicomputer in any HF position location system.

Thus far the limitations of a system using the sky wave have been the main topic. However, the ground wave can also be used in position location efforts, but again there are constraints and associated limitations. Use of the ground wave means that only the azimuthal angle of arrival can be determined and therefore more than one point of detection must be used to specify the location of the emitter. In addition, the ground wave can be used effectively only at ranges of less than 100 km (often very much less). While the many problems of ionospheric variability are avoided through use of the ground wave, an analogous set of problems also exists for this mode of propagation. Topography, soil type, and soil conductivity will change the true path of the ground wave from that of a segment of a great circle (that is, the shortest distance between two points on a smooth, uniformly conducting, spherical earth). Ground wave propagation has not been studied as extensively as direct wave or sky wave propagation, and many of these uncertainties still need to be quantified.

Another basic limitation for all types of HF-DF systems is that the location of the system itself must be known to a greater accuracy than the allowable error in range. For HF-DF systems which use the sky wave, with the associated large errors in attainable accuracy in position location, this limitation is not a major problem. However, when the desired accuracy in range is a fraction of a kilometer, the ability to determine one's own position even more precisely may become a severe limitation.

3. EXAMPLES OF SOME HF-DF RANGE ERRORS

The previous section points out that errors in HF-DF have several sources. Currently, we feel that HF-DF arrays have limits in resolution of the angle of arrival on the order of 1°; but for large arrays which are carefully surveyed, the error can be reduced to 0.1°. (This error is instrumentation error; actual propagation through the medium is another factor.) Practical constraints on the sizes of easily fielded systems generally yield angle acquisition errors on the order of 2°. Ionospheric tilt can introduce errors in the vertical angle of incidence on the order of 2° to 3°. The ionosphere is not a smoothly reflecting medium and produces a "corrugated" wavefront which in turn makes an exact determination of the angle of arrival difficult. The signal may travel different paths in the ionosphere and suffer varying degrees of

mentioned in the above categories. Resolution of the angles of arrival due to the limitations in antenna size implies that the reported value will tend to wander. Fading (even loss) of the signal can occur due to increased ionospheric absorption and several types of signal interference mechanisms. Multipath propagation of signals can cause problems in selection of the correct ionospheric parameters for the matching path and can also introduce interference fading. Co-channel interference involves the reception of unwanted, spurious signals and creates subsequent problems in signal discrimination. Also interference between the ordinary and extraordinary waves of the same signal can occur. Many of these problems have been mitigated in recent years through increasing use of computerized data handling and sophisticated software routines for signal processing and interpretation. To maintain and to improve these advances, a basic requirement would be the inclusion of a sophisticated minicomputer in any HF position location system.

Thus far the limitations of a system using the sky wave have been the main topic. However, the ground wave can also be used in position location efforts, but again there are constraints and associated limitations. Use of the ground wave means that only the azimuthal angle of arrival can be determined and therefore more than one point of detection must be used to specify the location of the emitter. In addition, the ground wave can be used effectively only at ranges of less than 100 km (often very much less). While the many problems of ionospheric variability are avoided through use of the ground wave, an analogous set of problems also exists for this mode of propagation. Topography, soil type, and soil conductivity will change the true path of the ground wave from that of a segment of a great circle (that is, the shortest distance between two points on a smooth, uniformly conducting, spherical earth). Ground wave propagation has not been studied as extensively as direct wave or sky wave propagation, and many of these uncertainties still need to be quantified.

Another basic limitation for all types of HF-DF systems is that the location of the system itself must be known to a greater accuracy than the allowable error in range. For HF-DF systems which use the sky wave, with the associated large errors in attainable accuracy in position location, this limitation is not a major problem. However, when the desired accuracy in range is a fraction of a kilometer, the ability to determine one's own position even more precisely may become a severe limitation.

3. EXAMPLES OF SOME HF-DF RANGE ERRORS

The previous section points out that errors in HF-DF have several sources. Currently, we feel that HF-DF arrays have limits in resolution of the angle of arrival on the order of 1°; but for large arrays which are carefully surveyed, the error can be reduced to 0.1°. (This error is instrumentation error; actual propagation through the medium is another factor.) Practical constraints on the sizes of easily fielded systems generally yield angle acquisition errors on the order of 2°. Ionospheric tilt can introduce errors in the vertical angle of incidence on the order of 2° to 3°. The ionosphere is not a smoothly reflecting medium and produces a "corrugated" wavefront which in turn makes an exact determination of the angle of arrival difficult. The signal may travel different paths in the ionosphere and suffer varying degrees of

absorption along these paths. In short, the ionosphere is the single largest source of error and may produce total errors in angle of arrival on the order of 10° for ranges larger than 300 km and up to 30° for ranges less than 300 km.

Figure 3 schematically illustrates some of the ionospheric irregularities mentioned previously which create errors in determining the true angle of arrival and in turn cause some of the problems in signal interruption also mentioned above. Some of the range determination errors inherent in HF-DF

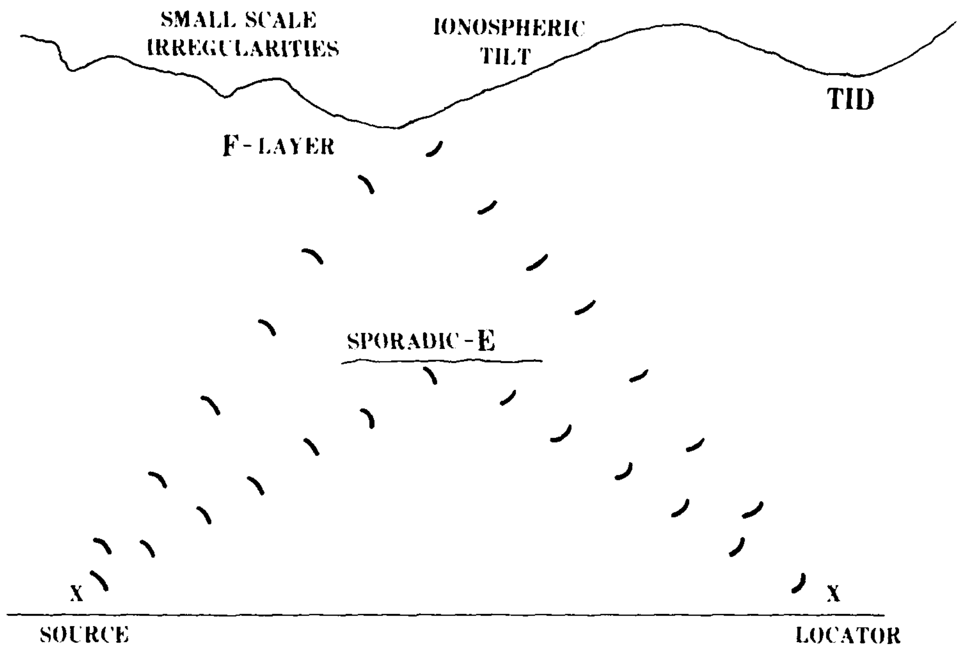

Figure 3. Origins of the uncertainty in the angle of arrival due to the ionosphere.

work can be quantified for a given situation. Table 1 shows potential position location errors for a source located 200 km from the HF-DF system. The general points to be gleaned from this table are that errors in the determination of the elevation angle are more severe than those affecting the azimuthal angle and that the errors associated with the system are generally smaller than those associated with the ionospheric variability. These factors again underscore the basic limitations due to ionospheric constraints.

The rule of thumb for currently attainable position location accuracies seems to be on the order of 20 km. Total time required to acquire, direction find, and locate a signal can be as short as 5 s, but in most circumstances would be longer.

4. OUTLINE OF HF-DF IMPROVEMENTS

Several areas where improvements in HF-DF position location accuracies can be obtained will now be outlined. Attention will be directed initially to the concept of the SSL which uses the sky wave as its means of detection.

absorption along these paths. In short, the ionosphere is the single largest source of error and may produce total errors in angle of arrival on the order of 10° for ranges larger than 300 km and up to 30° for ranges less than 300 km.

Figure 3 schematically illustrates some of the ionospheric irregularities mentioned previously which create errors in determining the true angle of arrival and in turn cause some of the problems in signal interruption also mentioned above. Some of the range determination errors inherent in HF-DF

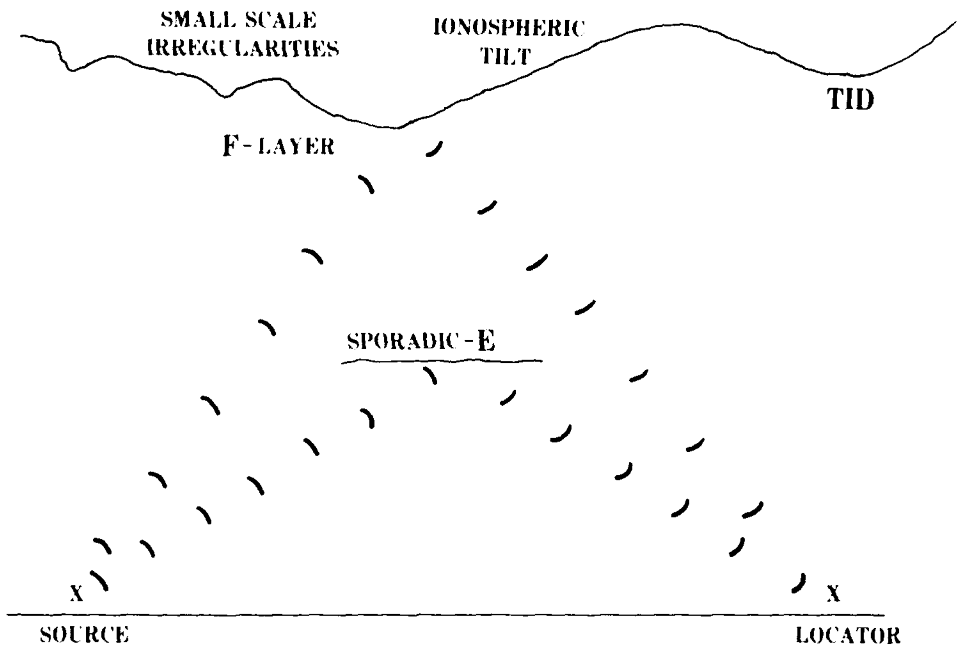

Figure 3. Origins of the uncertainty in the angle of arrival due to the ionosphere.

work can be quantified for a given situation. Table 1 shows potential position location errors for a source located 200 km from the HF-DF system. The general points to be gleaned from this table are that errors in the determination of the elevation angle are more severe than those affecting the azimuthal angle and that the errors associated with the system are generally smaller than those associated with the ionospheric variability. These factors again underscore the basic limitations due to ionospheric constraints.

The rule of thumb for currently attainable position location accuracies seems to be on the order of 20 km. Total time required to acquire, direction find, and locate a signal can be as short as 5 s, but in most circumstances would be longer.

4. OUTLINE OF HF-DF IMPROVEMENTS

Several areas where improvements in HF-DF position location accuracies can be obtained will now be outlined. Attention will be directed initially to the concept of the SSL which uses the sky wave as its means of detection.

TABLE 1. POTENTIAL ERRORS IN POSITION LOCATION

Distance: 200 km from emitter to locator

Reflecting Layers: E-layer at 120 km height and F-layer at 250 km height, one-hop mode

Type of Error	Typical Error	Errors in Range (km) E-layer	F-layer
Resolution limit of system	1°	7.0* 3.5	9.8 3.5
Variation of ionospheric height	10 km	16.3	7.7
Ionospheric tilt	2°	14.4 4.2	20.4 8.7

*Most types of errors create an ellipse of uncertainty about the true emitter location; when two values are listed, the upper value is the error in range and the second value is the cross-range (azimuthal) error.

The largest potential errors in position location are due to ionospheric variability. An ionosonde can be used to yield information on the height of the reflective ionospheric layer and to follow the time variations in this height. Current systems use a vertical ionosonde (that is, transmitter and receiver are colocated at the HF-DF site) which cannot yield detailed information on ionospheric tilts. Oblique soundings are recommended for use where two or more sounder transmitters are located some distance away from the receiver at the HF-DF site. The use of multiple oblique soundings will enable one to determine ionospheric tilts and provide some degree of resolution for other ionospheric irregularities. Currently the ionosphere can produce errors in the angle of arrival of the HF signal of several degrees which yield errors in the range of 20 km or larger. We believe that a more accurate determination of the ionosphere, when coupled to a ray retracing program, can yield accuracies on the order of 5 to 10 km. However, a basic limitation is that the state of the ionosphere cannot be measured at all points, and most particularly at the desired point of reflection. Thus extrapolation must be from a known point to a desired point; and it is this extrapolation which, in part, prevents attainment of accuracies of better than 5 to 10 km.

Table 1 has illustrated that a 1° error in the angle of arrival due to limits in resolution of the system produces errors in range on the order of 10 km. However, we now feel that such system resolution errors can be reduced to approximately 0.1°, which would mean effective errors in range on the order of 1 km.

Other areas of improvement are those of computer hardware and software and data processing and interpretation. The largest gains in the area of HF-DF accuracies in the last 5 to 10 years have been through better handling of the tremendous amounts of data which HF-DF can provide. With increased demands of

TABLE 1. POTENTIAL ERRORS IN POSITION LOCATION

Distance: 200 km from emitter to locator

Reflecting Layers: E-layer at 120 km height and F-layer at 250 km height, one-hop mode

Type of Error	Typical Error	Errors in Range (km) E-layer	Errors in Range (km) F-layer
Resolution limit of system	1°	7.0* 3.5	9.8 3.5
Variation of ionospheric height	10 km	16.3	7.7
Ionospheric tilt	2°	14.4 4.2	20.4 8.7

*Most types of errors create an ellipse of uncertainty about the true emitter location; when two values are listed, the upper value is the error in range and the second value is the cross-range (azimuthal) error.

The largest potential errors in position location are due to ionospheric variability. An ionosonde can be used to yield information on the height of the reflective ionospheric layer and to follow the time variations in this height. Current systems use a vertical ionosonde (that is, transmitter and receiver are colocated at the HF-DF site) which cannot yield detailed information on ionospheric tilts. Oblique soundings are recommended for use where two or more sounder transmitters are located some distance away from the receiver at the HF-DF site. The use of multiple oblique soundings will enable one to determine ionospheric tilts and provide some degree of resolution for other ionospheric irregularities. Currently the ionosphere can produce errors in the angle of arrival of the HF signal of several degrees which yield errors in the range of 20 km or larger. We believe that a more accurate determination of the ionosphere, when coupled to a ray retracing program, can yield accuracies on the order of 5 to 10 km. However, a basic limitation is that the state of the ionosphere cannot be measured at all points, and most particularly at the desired point of reflection. Thus extrapolation must be from a known point to a desired point; and it is this extrapolation which, in part, prevents attainment of accuracies of better than 5 to 10 km.

Table 1 has illustrated that a 1° error in the angle of arrival due to limits in resolution of the system produces errors in range on the order of 10 km. However, we now feel that such system resolution errors can be reduced to approximately 0.1°, which would mean effective errors in range on the order of 1 km.

Other areas of improvement are those of computer hardware and software and data processing and interpretation. The largest gains in the area of HF-DF accuracies in the last 5 to 10 years have been through better handling of the tremendous amounts of data which HF-DF can provide. With increased demands of

ray retracing techniques, more sophisticated hardware and software must be employed.

For systems which utilize modes of radio wave propagation other than the sky wave, a few general suggestions may be made. The magnitude of the potential uncertainties in ground wave and direct wave detection needs to be quantified and means explored of simultaneously using the weak ground wave and nearly vertical incident sky wave in the range of 50 to 100 km from the emitter. Direct wave DF is very system dependent (that is, platform dependent) and the range of these errors needs to be established.

5. PROPOSED PROGRAMS FOR HF-DF IMPROVEMENT

The considerations and limitations outlined in the previous sections would suggest two approaches to be followed in reducing the current errors in HF-DF location accuracies. The first approach, hereafter referred to as program A, is based on the concept of an SSL which is positioned some few hundred kilometers from the desired source and which uses the HF sky wave as a means of surveillance and location. The emphasis here is to extend the state of the art by using known technologies such that the limiting factor in HF position location becomes the basic ionospheric uncertainty. Such an approach has a good probability of meeting the established goals. The second approach, program B, would use a two-tier method of solution. The first tier incorporates program A to reduce the area of uncertainty in location to a circle of approximately 10 km diameter. The second tier would consist of mobile HF-DF units which would use either the ground wave or direct wave at much closer range to achieve the desired accuracies in position location. The second tier of program B implies a change in concept. Use of the sky wave, with its inherent uncertainty, is abandoned in favor of the ground wave or direct wave. The consequence is that the HF-DF unit must be about 50 km from the emitter and more than one mobile unit must be used. Attaining position location accuracies of less than 1 km thus implies noncomplementary trade-offs in range and complexity. Table 2 presents a brief outline of the programs.

6. CONCLUSIONS

The state-of-the-art HF-DF accuracies for surveillance and position location are 15 to 20 km at best for an SSL system. The sources of error in position location can be grouped into three categories:

- ionospheric variability and irregularity, < 20 km;

- antenna and system size limitations, 10 km; and

- data acquisition, processing, and interpretation.

The approximate errors in range have been indicated where appropriate. We believe that the above errors can be reduced to the following limits:

- ionospheric (propagation medium) induced errors, 5 to 10 km, and

- antenna and system induced errors, 1 to 2 km.

ray retracing techniques, more sophisticated hardware and software must be employed.

For systems which utilize modes of radio wave propagation other than the sky wave, a few general suggestions may be made. The magnitude of the potential uncertainties in ground wave and direct wave detection needs to be quantified and means explored of simultaneously using the weak ground wave and nearly vertical incident sky wave in the range of 50 to 100 km from the emitter. Direct wave DF is very system dependent (that is, platform dependent) and the range of these errors needs to be established.

5. PROPOSED PROGRAMS FOR HF-DF IMPROVEMENT

The considerations and limitations outlined in the previous sections would suggest two approaches to be followed in reducing the current errors in HF-DF location accuracies. The first approach, hereafter referred to as program A, is based on the concept of an SSL which is positioned some few hundred kilometers from the desired source and which uses the HF sky wave as a means of surveillance and location. The emphasis here is to extend the state of the art by using known technologies such that the limiting factor in HF position location becomes the basic ionospheric uncertainty. Such an approach has a good probability of meeting the established goals. The second approach, program B, would use a two-tier method of solution. The first tier incorporates program A to reduce the area of uncertainty in location to a circle of approximately 10 km diameter. The second tier would consist of mobile HF-DF units which would use either the ground wave or direct wave at much closer range to achieve the desired accuracies in position location. The second tier of program B implies a change in concept. Use of the sky wave, with its inherent uncertainty, is abandoned in favor of the ground wave or direct wave. The consequence is that the HF-DF unit must be about 50 km from the emitter and more than one mobile unit must be used. Attaining position location accuracies of less than 1 km thus implies noncomplementary trade-offs in range and complexity. Table 2 presents a brief outline of the programs.

6. CONCLUSIONS

The state-of-the-art HF-DF accuracies for surveillance and position location are 15 to 20 km at best for an SSL system. The sources of error in position location can be grouped into three categories:

- ionospheric variability and irregularity, $<$ 20 km;

- antenna and system size limitations, 10 km; and

- data acquisition, processing, and interpretation.

The approximate errors in range have been indicated where appropriate. We believe that the above errors can be reduced to the following limits:

- ionospheric (propagation medium) induced errors, 5 to 10 km, and

- antenna and system induced errors, 1 to 2 km.

TABLE 2. HF-DF ACCURACY IMPROVEMENTS

PROGRAM A	
Objective	Reduce the errors in HF position location accuracy from the current 15 to 20 km to 5 to 10 km.
Method of attack	Identify and quantify the ionospheric variability and irregularity which cause HF-DF uncertainties.
	Incorporate real-time ionospheric soundings and quantification from preceding step into ray retracing programs.
	Develop software to handle the demands of the above incorporation.
	Incorporate into operational HF-DF system.
Technical barriers	Adequate quantification of ionospheric structure.
	Development of ray retracing program to incorporate real-time ionospheric variability.
	Matching software to capabilities of operational system.
Probability of success	Good

PROGRAM B	
Objective	Improve the accuracies in HF surveillance and position location to fractions of a kilometer.
Method of attack	Design system to rely on the ground wave or direct wave.
	Use more than one mobile system to triangulate on emitter.
	Identify and quantify the uncertainties in ground wave HF direction finding.
	Establish procedure to fix locations of and coordinate efforts between multiple units.
Limitation	Effective range of detection is less than 100 km, more often on the order of 50 km or less.
Technical barriers	Adequate quantification of terrain effects on ground wave HF-DF.
	Means of accurately fixing the position of mobile units to fractions of a kilometer.
	Data exchange and processing between mobile units.
	Synthesis of tactically operable system.
Probability of success	Fair to good.

Such improvements depend on the continued incorporation of state-of-the-art computer hardware and software into the SSL to handle increased data processing requirements.

SSL surveillance and position location can be improved to accuracies of 5 to 10 km. Further improvement in HF DF accuracies may be attained by additional

Such improvements depend on the continued incorporation of state-of-the-art computer hardware and software into the SSL to handle increased data processing requirements.

SSL surveillance and position location can be improved to accuracies of 5 to 10 km. Further improvement in HF-DF accuracies may be attained by additional utilization of the HF ground wave or direct wave. Improvements in position location accuracies to fractions of a kilometer using these modes of HF propagation will involve noncomplementary trade-offs in other areas:

- Range of detection is reduced: 50 km or less for the ground-wave, on the order of 100 km for the direct-wave;

- Number of systems is increased: two or three mobile units would be deployed near the battle area; and

- Coordination and communication demands are increased.

Position location accuracies on the order of a fraction of a kilometer may possibly be achieved by using a ground wave or direct wave method of detection, but with the loss of certain advantages provided by a sky wave SSL. An integrated approach to the HF position location problem is recommended. This approach would employ all methods.

SELECTED BIBLIOGRAPHY

The following publications were useful source material for this report.

"AGARD Conference Proceedings No. 263, Special Topics in HF Propagation," in Proceedings of the Symposium of the Electro-magnetic Wave Propagation Panel, ed V. J. Coyne, held in Lisbon, Portugal, 28 May - 1 June 1979, Printed by Harford House, London, November 1979.

Baily, A. D., J. D. Dyson, and E. W. Ernst, 1972, HF/DF System Studies and Directional Propagation Research, Final Report (two volumes), ECOM-0097-F, US Army Electronic Warfare Laboratory, Fort Monmouth, NJ.

Ernst, E. W., J. D. Dyson, and N. N. Rao, 1974, HF/DF Techniques Investigation, Final Report (four volumes), ECOM-0125-F, US Army Electronic Warfare Laboratory, Fort Monmouth, NJ.

Fialer, P. A., 1970,, Irregularities in the Quiet Ionosphere and Their Effect on Propagation, Technical Report 156, Radioscience Laboratory, Standard Electronics Laboratories, Palo Alto, CA.

Georges, T. M., 1967, Ionospheric Effects of Atmospheric Waves, IER 57-ITSA 54, US Department of Commerce, Environmental Services Administration.

Jordan, E. C., E. W. Ernst, and W. W. Wood, 1972, Workshop on Future Directions of Radiolocation, Final Report, RRL Publication 421, University of Illinois, Urbana, IL.

Sweeney, L. E., Jr., 1970, Spatial Properties of Ionospheric Radio Propagation as Determined With Half-Degree Azimuthal Resolution, Technical Report 155, Radioscience Laboratory, Stanford Electronics Laboratories, Palo Alto, CA.

SELECTED BIBLIOGRAPHY

The following publications were useful source material for this report.

"AGARD Conference Proceedings No. 263, Special Topics in HF Propagation," in Proceedings of the Symposium of the Electro-magnetic Wave Propagation Panel, ed V. J. Coyne, held in Lisbon, Portugal, 28 May - 1 June 1979, Printed by Harford House, London, November 1979.

Baily, A. D., J. D. Dyson, and E. W. Ernst, 1972, HF/DF System Studies and Directional Propagation Research, Final Report (two volumes), ECOM-0097-F, US Army Electronic Warfare Laboratory, Fort Monmouth, NJ.

Ernst, E. W., J. D. Dyson, and N. N. Rao, 1974, HF/DF Techniques Investigation, Final Report (four volumes), ECOM-0125-F, US Army Electronic Warfare Laboratory, Fort Monmouth, NJ.

Fialer, P. A., 1970,, Irregularities in the Quiet Ionosphere and Their Effect on Propagation, Technical Report 156, Radioscience Laboratory, Standard Electronics Laboratories, Palo Alto, CA.

Georges, T. M., 1967, Ionospheric Effects of Atmospheric Waves, IER 57-ITSA 54, US Department of Commerce, Environmental Services Administration.

Jordan, E. C., E. W. Ernst, and W. W. Wood, 1972, Workshop on Future Directions of Radiolocation, Final Report, RRL Publication 421, University of Illinois, Urbana, IL.

Sweeney, L. E., Jr., 1970, Spatial Properties of Ionospheric Radio Propagation as Determined With Half-Degree Azimuthal Resolution, Technical Report 155, Radioscience Laboratory, Stanford Electronics Laboratories, Palo Alto, CA.

ELECTRO-OPTICS DISTRIBUTION LIST

Commander
US Army Aviation School
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MA (Mr. Oliver N. Heath)
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MS (Mr. Donald Wagner)
Fort Rucker, AL 36362

NASA/Marshall Space Flight Center
ATTN: ES-83 (Otha H. Vaughan, Jr.)
Huntsville, AL 35812

NASA/Marshall Space Flight Center
Atmospheric Sciences Division
ATTN: Code ES-81 (Dr. William W. Vaughan)
Huntsville, AL 35812

Nichols Research Corporation
ATTN: Dr. Lary W. Pinkley
4040 South Memorial Parkway
Huntsville, AL 35802

John M. Hobbie
c/o Kentron International
2003 Byrd Spring Road
Huntsville, AL 35802

Mr. Ray Baker
Lockheed-Missile & Space Company
4800 Bradford Blvd
Huntsville, AL 35807

Commander
US Army Missile Command
ATTN: DRSMI-OG (Mr. Donald R. Peterson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-OGA (Dr. Bruce W. Fowler)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REL (Dr. George Emmons)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Huey F. Anderson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Maxwell W. Harper)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Gene Widenhofer)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RHC (Dr. Julius Q. Lilly)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
Redstone Scientific Information Center
ATTN: DRSMI-RPRD (Documents Section)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRA (Dr. Oskar Essenwanger)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Mr. Charles Christensen)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Dr. George A. Tanton)
Redstone Arsenal, AL 35809

Commander
US Army Communications Command
ATTN: CC-OPS-PP
Fort Huachuca, AZ 85613

ELECTRO-OPTICS DISTRIBUTION LIST

Commander
US Army Aviation School
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MA (Mr. Oliver N. Heath)
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MS (Mr. Donald Wagner)
Fort Rucker, AL 36362

NASA/Marshall Space Flight Center
ATTN: ES-83 (Otha H. Vaughan, Jr.)
Huntsville, AL 35812

NASA/Marshall Space Flight Center
Atmospheric Sciences Division
ATTN: Code ES-81 (Dr. William W. Vaughan)
Huntsville, AL 35812

Nichols Research Corporation
ATTN: Dr. Lary W. Pinkley
4040 South Memorial Parkway
Huntsville, AL 35802

John M. Hobbie
c/o Kentron International
2003 Byrd Spring Road
Huntsville, AL 35802

Mr. Ray Baker
Lockheed-Missile & Space Company
4800 Bradford Blvd
Huntsville, AL 35807

Commander
US Army Missile Command
ATTN: DRSMI-OG (Mr. Donald R. Peterson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-OGA (Dr. Bruce W. Fowler)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REL (Dr. George Emmons)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Huey F. Anderson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Maxwell W. Harper)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Gene Widenhofer)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RHC (Dr. Julius Q. Lilly)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
Redstone Scientific Information Center
ATTN: DRSMI-RPRD (Documents Section)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRA (Dr. Oskar Essenwanger)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Mr. Charles Christensen)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Dr. George A. Tanton)
Redstone Arsenal, AL 35809

Commander
US Army Communications Command
ATTN: CC-OPS-PP
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-CS (Mr. Richard G. Cundy)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-MD (Mr. Harry Wilder)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CS-C (2LT Coffman)
Fort Huachuca, AZ 85613

Commander
US Army Yuma Proving Ground
ATTN: STEYP-MSA-TL
Bldg 2105
Yuma, AZ 85364

Northrop Corporation
Electro-Mechanical Division
ATTN: Dr. Richard D. Tooley
500 East Orangethorpe Avenue
Anaheim, CA 92801

Commander
Naval Weapons Center
ATTN: Code 3918 (Dr. Alexis Shlanta)
China Lake, CA 93555

Hughes Helicopters
Army Advanced Attack Helicopter Weapons
ATTN: Mr. Charles R. Hill
Centinela and Teale Streets
Bldg 305, MS T-73A
Culter City, CA 90230

Commander
US Army Combat Developments
Experimentation Command
ATTN: ATEC-PL-M (Mr. Gary G. Love)
Fort Ord, CA 93941

SRI International
ATTN: K2060/Dr. Edward E. Uthe
333 Ravenswood Avenue
Menlo Park, CA 94025

SRI International
ATTN: Mr. J. E. Van der Laan
333 Ravenswood Avenue
Menlo Park, CA 94025

Joane May
Naval Environmental Prediction
Research Facility (NEPRF)
ATTN: Library
Monterey, CA 93940

Sylvania Systems Group,
Western Division
GTE Products Corporation
ATTN: Technical Reports Library
P.O. Box 205
Mountain View, CA 94042

Sylvania Systems Group
Western Division
GTE Products Corporation
ATTN: Mr. Lee W. Carrier
P.O. Box 188
Mountain View, CA 94042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3253
Point Mugu, CA 93042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3253 (Terry E. Battalino)
Point Mugu, CA 93042

Effects Technology Inc.
ATTN: Mr. John D. Carlyle
5383 Hollister Avenue
Santa Barbara, CA 93111

Commander
Naval Ocean Systems Center
ATTN: Code 532 (Dr. Juergen Richter)
San Diego, CA 92152

Commander
Naval Ocean Systems Center
ATTN: Code 5322 (Mr. Herbert G. Hughes)
San Diego, CA 92152

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-CS (Mr. Richard G. Cundy)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-MD (Mr. Harry Wilder)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CS-C (2LT Coffman)
Fort Huachuca, AZ 85613

Commander
US Army Yuma Proving Ground
ATTN: STEYP-MSA-TL
Bldg 2105
Yuma, AZ 85364

Northrop Corporation
Electro-Mechanical Division
ATTN: Dr. Richard D. Tooley
500 East Orangethorpe Avenue
Anaheim, CA 92801

Commander
Naval Weapons Center
ATTN: Code 3918 (Dr. Alexis Shlanta)
China Lake, CA 93555

Hughes Helicopters
Army Advanced Attack Helicopter Weapons
ATTN: Mr. Charles R. Hill
Centinela and Teale Streets
Bldg 305, MS T-73A
Culter City, CA 90230

Commander
US Army Combat Developments
Experimentation Command
ATTN: ATEC-PL-M (Mr. Gary G. Love)
Fort Ord, CA 93941

SRI International
ATTN: K2060/Dr. Edward E. Uthe
333 Ravenswood Avenue
Menlo Park, CA 94025

SRI International
ATTN: Mr. J. E. Van der Laan
333 Ravenswood Avenue
Menlo Park, CA 94025

Joane May
Naval Environmental Prediction
Research Facility (NEPRF)
ATTN: Library
Monterey, CA 93940

Sylvania Systems Group,
Western Division
GTE Products Corporation
ATTN: Technical Reports Library
P.O. Box 205
Mountain View, CA 94042

Sylvania Systems Group
Western Division
GTE Products Corporation
ATTN: Mr. Lee W. Carrier
P.O. Box 188
Mountain View, CA 94042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3253
Point Mugu, CA 93042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3253 (Terry E. Battalino)
Point Mugu, CA 93042

Effects Technology Inc.
ATTN: Mr. John D. Carlyle
5383 Hollister Avenue
Santa Barbara, CA 93111

Commander
Naval Ocean Systems Center
ATTN: Code 532 (Dr. Juergen Richter)
San Diego, CA 92152

Commander
Naval Ocean Systems Center
ATTN: Code 5322 (Mr. Herbert G. Hughes)
San Diego, CA 92152

Commander
Naval Ocean Systems Center
ATTN: Code 4473 (Tech Library)
San Diego, CA 92152

The RAND Corporation
ATTN: Ralph Huschke
1700 Main Street
Santa Monica, CA 90406

Particle Measuring Systems, Inc.
ATTN: Dr. Robert G. Knollenberg
1855 South 57th Court
Boulder, CO 80301

US Department of Commerce
National Oceanic and Atmospheric Admin
Environmental Research Laboratories
ATTN: Library, R-51, Technical Reports
325 Broadway
Boulder, CO 80303

US Department of Commerce
National Oceanic and Atmospheric Admin
Environmental Research Laboratories
ATTN: R45X3 (Dr. Vernon E. Derr)
Boulder, CO 80303

US Department of Commerce
National Telecommunications and
Information Administration
Institute for Telecommunication Sciences
ATTN: Code 1-3426 (Dr. Hans J. Liebe)
Boulder, CO 80303

AFATL/DLODL
Technical Library
Eglin AFB, FL 32542

Commanding Officer
Naval Training Equipment Center
ATTN: Technical Information Center
Orlando, FL 32813

Georgia Institute of Technology
Engineering Experiment Station
ATTN: Dr. Robert W. McMillan
Atlanta, GA 30332

Georgia Institute of Technology
Engineering Experiment Station
ATTN: Dr. James C. Wiltse
Atlanta, GA 30332

Commandant
US Army Infantry Center
ATTN: ATSH-CD-MS-E (Mr. Robert McKenna)
Fort Benning, GA 31805

Commander
US Army Signal Center & Fort Gordon
ATTN: ATZHCD-CS
Fort Gordon, GA 30905

Commander
US Army Signal Center & Fort Gordon
ATTN: ATZHCD-O
Fort Gordon, GA 30905

USAFETAC/DNE
ATTN: Mr. Charles Glauber
Scott AFB, IL 62225

Commander
Air Weather Service
ATTN: AWS/DNDP (LTC Kit G. Cottrell)
Scott AFB, IL 62225

Commander
Air Weather Service
ATTN: AWS/DOOF (MAJ Robert Wright)
Scott AFB, IL 62225

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-CAA-Q (Mr. H. Kent Pickett)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-SAN (Robert DeKinder, Jr.)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-SAN (Mr. Kent I. Johnson)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-WE (LTC Darrell Holland)
Fort Leavenworth, KS 66027

President
USAARENBD
ATTN: ATZK-AE-TA (Dr. Charles R. Leake)
Fort Knox, KY 40121

Commander
US Army Armor Center and Fort Knox
ATTN: ATZK-CD-MS
Fort Knox, KY 40121

Commander
US Army Armor Center and Fort Knox
ATTN: ATZK-CD-SD
Fort Knox, KY 40121

Aerodyne Research Inc.
ATTN: Dr. John F. Ebersole
Crosby Drive
Bedford, MA 01730

Commander
Air Force Geophysics Laboratory
ATTN: OPA (Dr. Robert W. Fenn)
Hanscom AFB, MA 01731

Commander
Air Force Geophysics Laboratory
ATTN: OPI (Dr. Robert A. McClatchey)
Hanscom AFB, MA 01731

Massachusetts Institute of Technology
Lincoln Laboratory
ATTN: Dr. T. J. Goblick, B-370
P.O. Box 73
Lexington, MA 02173

Massachusetts Institute of Technology
Lincoln Laboratory
ATTN: Dr. Michael Gruber
P.O. Box 73
Lexington, MA 02173

Raytheon Company
Equipment Division
ATTN: Dr. Charles M. Sonnenschein
430 Boston Post Road
Wayland, MA 01778

Commander
US Army Ballistic Research Laboratory/
ARRADCOM
ATTN: DRDAR-BLB (Mr. Richard McGee)
Aberdeen Proving Ground, MD 21005

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLB-PS (Dr. Edward Stuebing)
Aberdeen Proving Ground, MD 21010

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLB-PS (Mr. Joseph Vervier)
Aberdeen Proving Ground, MD 21010

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLY-A (Mr. Ronnald Pennsyle)
Aberdeen Proving Ground, MD 21010

Commander
US Army Ballistic Research Laboratory/
ARRADCOM
ATTN: DRDAR-TSB-S (STINFO)
Aberdeen Proving Ground, MD 21005

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CCM (W. H. Pepper)
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CG/DRDEL-DC/DRDEL-CS
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CT
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-PAO (Mr. Steven Kimmel)
2800 Powder Mill Road
Adelphi, MD 20783

Project Manager
Smoke/Obscurants
ATTN: DRDPM-SMK
(Dr. Anthony Van de Wal, Jr.)
Aberdeen Proving Ground, MD 21005

Project Manager
Smoke/Obscurants
ATTN: DRDPM-SMK-T (Mr. Sidney Gerard)
Aberdeen Proving Ground, MD 21005

Commander
US Army Test & Evaluation Command
ATTN: DRSTE-AD-M (Mr. Warren M. Baity)
Aberdeen Proving Ground, MD 21005

Commander
US Army Test & Evaluation Command
ATTN: DRSTE-AD-M (Dr. Norman E. Pentz)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-AAM (Mr. William Smith)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-CS (Mr. Philip H. Beavers)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GB (Wilbur L. Warfield)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GP (Mr. Fred Campbell)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GS
(Mr. Michael Starks/Mr. Julian Chernick)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-J (Mr James F. O'Bryon)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-LM (Mr. Robert M. Marchetti)
Aberdeen Proving Ground, MD 21005

Commander
Harry Diamond Laboratories
ATTN: Dr. William W. Carter
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM (Mr. Robert McCoskey)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Robert Humphrey)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Z. G. Sztankay)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Joseph Nemarich)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Air Force Systems Command
ATTN: WER (Mr. Richard F. Picanso)
Andrews AFB, MD 20334

Martin Marietta Laboratories
ATTN: Jar Mo Chen
1450 South Rolling Road
Baltimore, MD 21227

Commander
US Army Concepts Analysis Agency
ATTN: CSCA-SMC (Mr. Hal E. Hock)
8120 Woodmont Avenue
Bethesda, MD 20014

Director
National Security Agency
ATTN: R52/Dr. Douglas Woods
Fort George G. Meade, MD 20755

Chief
Intelligence Materiel Development
& Support Office
US Army Electronic Warfare Laboratory
ATTN: DELEW-I (LTC Kenneth E. Thomas)
Fort George G. Meade, MD 20755

The John Hopkins University
Applied Physics Laboratory
ATTN: Dr. Michael J. Lun
John Hopkins Road
Laurell, MD 20810

Dr. Stephen T. Hanley
1720 Rhodesia Avenue
Oxon Hill, MD 20022

Science Applications Inc.
ATTN: Mr. G. D. Currie
15 Research Drive
Ann Arbor, MI 48103

Science Applications Inc.
ATTN: Dr. Robert E. Turner
15 Research Drive
Ann Arbor, MI 48103

Commander
US Army Tank-Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Harry Young)
Warren, MI 48090

Commander
US Army Tank Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Wallace Mick, Jr.)
Warren, MI 48090

Dr. A. D. Belmont
Research Division
Control Data Corporation
P.O. Box 1249
Minneapolis, MN 55440

Director
US Army Engr Waterways Experiment Station
ATTN: WESEN (Mr. James Mason)
P.O. Box 631
Vicksburg, MS 39180

Commander
US Army Research Office
ATTN: DRXRO-GS (Dr. Leo Alpert)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Research Office
ATTN: DRXRO-PP (Brenda Mann)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RD (Dr. K. F. Sterrett)
Hanover, NH 03755

Commander/Director
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. George Aitken)
Hanover, NH 03755

Commander
Air Force Systems Command
ATTN: WER (Mr. Richard F. Picanso)
Andrews AFB, MD 20334

Martin Marietta Laboratories
ATTN: Jar Mo Chen
1450 South Rolling Road
Baltimore, MD 21227

Commander
US Army Concepts Analysis Agency
ATTN: CSCA-SMC (Mr. Hal E. Hock)
8120 Woodmont Avenue
Bethesda, MD 20014

Director
National Security Agency
ATTN: R52/Dr. Douglas Woods
Fort George G. Meade, MD 20755

Chief
Intelligence Materiel Development
& Support Office
US Army Electronic Warfare Laboratory
ATTN: DELEW-I (LTC Kenneth E. Thomas)
Fort George G. Meade, MD 20755

The John Hopkins University
Applied Physics Laboratory
ATTN: Dr. Michael J. Lun
John Hopkins Road
Laurell, MD 20810

Dr. Stephen T. Hanley
1720 Rhodesia Avenue
Oxon Hill, MD 20022

Science Applications Inc.
ATTN: Mr. G. D. Currie
15 Research Drive
Ann Arbor, MI 48103

Science Applications Inc.
ATTN: Dr. Robert E. Turner
15 Research Drive
Ann Arbor, MI 48103

Commander
US Army Tank-Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Harry Young)
Warren, MI 48090

Commander
US Army Tank Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Wallace Mick, Jr.)
Warren, MI 48090

Dr. A. D. Belmont
Research Division
Control Data Corporation
P.O. Box 1249
Minneapolis, MN 55440

Director
US Army Engr Waterways Experiment Station
ATTN: WESEN (Mr. James Mason)
P.O. Box 631
Vicksburg, MS 39180

Commander
US Army Research Office
ATTN: DRXRO-GS (Dr. Leo Alpert)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Research Office
ATTN: DRXRO-PP (Brenda Mann)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RD (Dr. K. F. Sterrett)
Hanover, NH 03755

Commander/Director
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. George Aitken)
Hanover, NH 03755

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. Roger H. Berger)
Hanover, NH 03755

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-AC (Mr. James Greenfield)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-TSS (Bldg #59)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. Peteris Jansons)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. G. H. Waldron)
Dover, NJ 07801

Deputy Joint Project Manager
for Navy/USMC SAL GP
ATTN: DRCPM-CAWS-NV (CPT Joseph Miceli)
Dover, NJ 07801

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-I (Mr. David Longinotti)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-PE (Mr. Ben A. Di Campli)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-R-S (Mr. Donald L. Foiani)
Fort Monmouth, NJ 07703

Director
US Army Electronics Technology &
Devices Laboratory
ATTN: DELET-DD (S. Danko)
Fort Monmouth, NJ 07703

Project Manager
FIREFINDER/REMBASS
ATTN: DRCPM-FFR-TM (Mr. John M. Bialo)
Fort Monmouth, NJ 07703

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-SA (Dr. Walter S. McAfee)
Fort Monmouth, NJ 07703

OLA, 2WS (MAC)
Holloman AFB, NM 88330

Commander
Air Force Weapons Laboratory
ATTN: AFWL/WE (MAJ John R. Elrick)
Kirtland, AFB, NM 87117

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL (Dolores Anguiano)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. Louie Dominguez)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. William J. Leach)
White Sands Missile Range, NM 88002

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. Roger H. Berger)
Hanover, NH 03755

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-AC (Mr. James Greenfield)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-TSS (Bldg #59)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. Peteris Jansons)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. G. H. Waldron)
Dover, NJ 07801

Deputy Joint Project Manager
for Navy/USMC SAL GP
ATTN: DRCPM-CAWS-NV (CPT Joseph Miceli)
Dover, NJ 07801

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-I (Mr. David Longinotti)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-PE (Mr. Ben A. Di Campli)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-R-S (Mr. Donald L. Foiani)
Fort Monmouth, NJ 07703

Director
US Army Electronics Technology &
Devices Laboratory
ATTN: DELET-DD (S. Danko)
Fort Monmouth, NJ 07703

Project Manager
FIREFINDER/REMBASS
ATTN: DRCPM-FFR-TM (Mr. John M. Bialo)
Fort Monmouth, NJ 07703

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-SA (Dr. Walter S. McAfee)
Fort Monmouth, NJ 07703

OLA, 2WS (MAC)
Holloman AFB, NM 88330

Commander
Air Force Weapons Laboratory
ATTN: AFWL/WE (MAJ John R. Elrick)
Kirtland, AFB, NM 87117

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL (Dolores Anguiano)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. Louie Dominguez)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. William J. Leach)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TGP (Mr. Roger F. Willis)
White Sands Missile Range, NM 88002

Director
Office of Missile Electronic Warfare
ATTN: DELEW-M-STO (Dr. Steven Kovel)
White Sands Missile Range, NM 88002

Office of the Test Director
Joint Services EO GW CM Test Program
ATTN: DRXDE-TD (Mr. Weldon Findley)
White Sands Missile Range, NM 88002

Commander
US Army White Sands Missile Range
ATTN: STEWS-PT-AL (Laurel B. Saunders)
White Sands Missile Range, NM 88002

Commander
US Army R&D Coordinator
US Embassy - Bonn
Box 165
APO New York 09080

Grumman Aerospace Corporation
Research Department - MS A08-35
ATTN: John E. A. Selby
Bethpage, NY 11714

Rome Air Development Center
ATTN: Documents Library
TSLD (Bette Smith)
Griffiss AFB, NY 13441

Dr. Roberto Vaglio-Laurin
Faculty of Arts and Science
Dept. of Applied Science
26-36 Stuyvesant Street
New York, NY 10003

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (Mr. Harold Geltmacher)
Wright-Patterson AFB, OH 45433

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (CPT William C. Smith)
Wright-Patterson AFB, OH 45433

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R (CPT James M. Watson)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CD-MS
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: NOAA Liaison Officer
(CDR Jeffrey G. Carlen)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
Morris Swett Library
ATTN: Reference Librarian
Fort Sill, OK 73503

Commander
Naval Air Development Center
ATTN: Code 301 (Mr. George F. Eck)
Warminster, PA 18974

The University of Texas at El Paso
Electrical Engineering Department
ATTN: Dr. Joseph H. Pierluissi
El Paso, TX 79968

Commandant
US Army Air Defense School
ATTN: ATSA-CD-SC-A (CPT Charles T. Thorn)
Fort Bliss, TX 79916

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TGP (Mr. Roger F. Willis)
White Sands Missile Range, NM 88002

Director
Office of Missile Electronic Warfare
ATTN: DELEW-M-STO (Dr. Steven Kovel)
White Sands Missile Range, NM 88002

Office of the Test Director
Joint Services EO GW CM Test Program
ATTN: DRXDE-TD (Mr. Weldon Findley)
White Sands Missile Range, NM 88002

Commander
US Army White Sands Missile Range
ATTN: STEWS-PT-AL (Laurel B. Saunders)
White Sands Missile Range, NM 88002

Commander
US Army R&D Coordinator
US Embassy - Bonn
Box 165
APO New York 09080

Grumman Aerospace Corporation
Research Department - MS A08-35
ATTN: John E. A. Selby
Bethpage, NY 11714

Rome Air Development Center
ATTN: Documents Library
TSLD (Bette Smith)
Griffiss AFB, NY 13441

Dr. Roberto Vaglio-Laurin
Faculty of Arts and Science
Dept. of Applied Science
26-36 Stuyvesant Street
New York, NY 10003

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (Mr. Harold Geltmacher)
Wright-Patterson AFB, OH 45433

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (CPT William C. Smith)
Wright-Patterson AFB, OH 45433

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R (CPT James M. Watson)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CD-MS
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: NOAA Liaison Officer
(CDR Jeffrey G. Carlen)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
Morris Swett Library
ATTN: Reference Librarian
Fort Sill, OK 73503

Commander
Naval Air Development Center
ATTN: Code 301 (Mr. George F. Eck)
Warminster, PA 18974

The University of Texas at El Paso
Electrical Engineering Department
ATTN: Dr. Joseph H. Pierluissi
El Paso, TX 79968

Commandant
US Army Air Defense School
ATTN: ATSA-CD-SC-A (CPT Charles T. Thorn)
Fort Bliss, TX 79916

Commander
HQ, TRADOC Cobmined Arms Test Activity
ATTN: ATCAT-OP-Q (CPT Henry C. Cobb, Jr.)
Fort Hood, TX 76544

Commander
HQ, TRADOC Combined Arms Test Activity
ATTN: ATCAT-SCI (Dr. Darrell W. Collier)
Fort Hood, TX 76544

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-L
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-M (Mr. Paul E. Carlson)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. John Trethewey)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. William Peterson)
Dugway, UT 84022

Defense Documentation Center
ATTN: DDC-TCA
Cameron Station Bldg 5
Alexandria, VA 22314
12

Ballistic Missile Defense Program Office
ATTN: DACS-BMT (Colonel Harry F. Ennis)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Technical Information Center
ATTN: DDA-2 (Mr. James E. Shafer)
Cameron Station, Bldg 5
Alexandria, VA 22314

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCBSI-EE (Mr. Albert Giambalvo)
5001 Eisenhower Avenue
Alexandria, VA 22333

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCLDC (Mr. James Bender)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Advanced Rsch Projects Agency
ATTN: Steve Zakanyez
1400 Wilson Blvd
Arlington, VA 22209

Defense Advanced Rsch Projects Agency
ATTN: Dr. James Tegnelia
1400 Wilson Blvd
Arlington, VA 22209

Institute for Defense Analyses
ATTN: Mr. Lucien M. Biberman
400 Army-Navy Drive
Arlington, VA 22202

Institute for Defense Analyses
ATTN: Dr. Ernest Bauer
400 Army-Navy Drive
Arlington, VA 22202

Institute of Defense Analyses
ATTN: Dr. Hans G. Wolfhard
400 Army-Navy Drive
Arlingon, VA 22202

System Planning Corporation
ATTN: Mr. Daniel Friedman
1500 Wilson Boulevard
Arlington, VA 22209

System Planning Corporation
ATTN: COL Hank Shelton
1500 Wilson Boulevard
Arlington, VA 22209

Commander
HQ, TRADOC Cobmined Arms Test Activity
ATTN: ATCAT-OP-Q (CPT Henry C. Cobb, Jr.)
Fort Hood, TX 76544

Commander
HQ, TRADOC Combined Arms Test Activity
ATTN: ATCAT-SCI (Dr. Darrell W. Collier)
Fort Hood, TX 76544

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-L
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-M (Mr. Paul E. Carlson)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. John Trethewey)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. William Peterson)
Dugway, UT 84022

Defense Documentation Center
ATTN: DDC-TCA
Cameron Station Bldg 5
Alexandria, VA 22314
12

Ballistic Missile Defense Program Office
ATTN: DACS-BMT (Colonel Harry F. Ennis)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Technical Information Center
ATTN: DDA-2 (Mr. James E. Shafer)
Cameron Station, Bldg 5
Alexandria, VA 22314

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCBSI-EE (Mr. Albert Giambalvo)
5001 Eisenhower Avenue
Alexandria, VA 22333

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCLDC (Mr. James Bender)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Advanced Rsch Projects Agency
ATTN: Steve Zakanyez
1400 Wilson Blvd
Arlington, VA 22209

Defense Advanced Rsch Projects Agency
ATTN: Dr. James Tegnelia
1400 Wilson Blvd
Arlington, VA 22209

Institute for Defense Analyses
ATTN: Mr. Lucien M. Biberman
400 Army-Navy Drive
Arlington, VA 22202

Institute for Defense Analyses
ATTN: Dr. Ernest Bauer
400 Army-Navy Drive
Arlington, VA 22202

Institute of Defense Analyses
ATTN: Dr. Hans G. Wolfhard
400 Army-Navy Drive
Arlingon, VA 22202

System Planning Corporation
ATTN: Mr. Daniel Friedman
1500 Wilson Boulevard
Arlington, VA 22209

System Planning Corporation
ATTN: COL Hank Shelton
1500 Wilson Boulevard
Arlington, VA 22209

US Army Intelligence & Security Command
ATTN: Edwin Speakman, Scientific Advisor
Arlington Hall Station
Arlington, VA 22212

Commander
US Army Operational Test
& Evaluation Agency
ATTN: CSTE-ED (Mr. Floyd I. Hill)
5600 Columbia Pike
Falls Church, VA 22041

Commander and Director
US Army Engineer Topographic Laboratories
ATTN: ETL-GS-A (Mr. Thomas Neidringhaus)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Rudolf G. Buser)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Robert S. Rodhe)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Joseph R. Moulton)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Luanne P. Obert)
Fort Belvoir, VA 22060

Director
US Army Night Vision
& Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Thomas W. Cassidy)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Richard J. Bergemann)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Dr. James A. Ratches)
Fort Belvoir, VA 22060

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN-M
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-F-A (Mr. Chris O'Connor, Jr.)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-IE-R (Mr. David M. Ingram)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-M-I/ATCD-M-A
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATDOC-TA (Dr. Marvin P. Pastel)
Fort Monroe, VA 23651

Department of the Air Force
OL-I, AWS
Fort Monroe, VA 23651

Department of the Air Force
HQS 5 Weather Wing (MAC)
ATTN: 5 WW/DN
Langley Air Force Base, VA 23655

US Army Intelligence & Security Command
ATTN: Edwin Speakman, Scientific Advisor
Arlington Hall Station
Arlington, VA 22212

Commander
US Army Operational Test
& Evaluation Agency
ATTN: CSTE-ED (Mr. Floyd I. Hill)
5600 Columbia Pike
Falls Church, VA 22041

Commander and Director
US Army Engineer Topographic Laboratories
ATTN: ETL-GS-A (Mr. Thomas Neidringhaus)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Rudolf G. Buser)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Robert S. Rodhe)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Joseph R. Moulton)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Luanne P. Obert)
Fort Belvoir, VA 22060

Director
US Army Night Vision
& Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Thomas W. Cassidy)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Richard J. Bergemann)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Dr. James A. Ratches)
Fort Belvoir, VA 22060

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN-M
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-F-A (Mr. Chris O'Connor, Jr.)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-IE-R (Mr. David M. Ingram)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-M-I/ATCD-M-A
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATDOC-TA (Dr. Marvin P. Pastel)
Fort Monroe, VA 23651

Department of the Air Force
OL-I, AWS
Fort Monroe, VA 23651

Department of the Air Force
HQS 5 Weather Wing (MAC)
ATTN: 5 WW/DN
Langley Air Force Base, VA 23655

Commander
US Army INSCOM/Quest Research Corporation
ATTN: Mr. Donald Wilmot
6845 Elm Street, Suite 407
McLean, VA 22101

General Research Corporation
ATTN: Dr. Ralph Zirkind
7655 Old Springhouse Road
McLean, VA 22102

Science Applications, Inc.
8400 Westpark Drive
ATTN: Dr. John E. Cockayne
McLean, VA 22102

US Army Nuclear & Chemical Agency
ATTN: MONA-WE (Dr. John A. Berberet)
7500 Backlick Road, Bldg 2073
Springfield, VA 22150

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-EA (Mr. Douglas Harkleroad)
Vint Hill Farms Station
Warrenton, VA 22186

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-OS (Dr. Royal H. Burkhardt)
Vint Hill Farms Station
Warrenton, VA 22186

Commander
US Army Cold Regions Test Center
ATTN: STECR-TD (Mr. Jerold Barger)
APO Seattle, WA 98733

HQDA (SAUS-OR/Hunter M. Woodall, Jr./
Dr. Herbert K. Fallin)
Rm 2E 614, Pentagon
Washington, DC 20301

COL Elbert W. Friday, Jr.
OUSDRE
Rm 3D 129, Pentagon
Washington, DC 20301

Defense Communications Agency
Technical Library Center
Code 222
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: Technical Library (Mrs. Betty Fox)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: RAAE (Dr. Carl Fitz)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: SPAS (Mr. Donald J. Kohler)
Washington, DC 20305

Defense Intelligence Agency
ATTN: DT/AC (LTC Robert Poplawski)
Washington, DC 20301

HQDA (DAMA-ARZ-D/Dr. Verderame)
Washington, DC 20310

HQDA (DAMI-ISP/Mr. Beck)
Washington, DC 20310

Department of the Army
Deputy Chief of Staff for
Operations and Plans
ATTN: DAMO-RQ
Washington, DC 20310

Department of the Army
Director of Telecommunications and
Command and Control
ATTN: DAMO-TCZ
Washington, DC 20310

Department of the Army
Assistant Chief of Staff for Intelligence
ATTN: DAMI-TS
Washington, DC 20310

Commander
US Army INSCOM/Quest Research Corporation
ATTN: Mr. Donald Wilmot
6845 Elm Street, Suite 407
McLean, VA 22101

General Research Corporation
ATTN: Dr. Ralph Zirkind
7655 Old Springhouse Road
McLean, VA 22102

Science Applications, Inc.
8400 Westpark Drive
ATTN: Dr. John E. Cockayne
McLean, VA 22102

US Army Nuclear & Chemical Agency
ATTN: MONA-WE (Dr. John A. Berberet)
7500 Backlick Road, Bldg 2073
Springfield, VA 22150

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-EA (Mr. Douglas Harkleroad)
Vint Hill Farms Station
Warrenton, VA 22186

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-OS (Dr. Royal H. Burkhardt)
Vint Hill Farms Station
Warrenton, VA 22186

Commander
US Army Cold Regions Test Center
ATTN: STECR-TD (Mr. Jerold Barger)
APO Seattle, WA 98733

HQDA (SAUS-OR/Hunter M. Woodall, Jr./
Dr. Herbert K. Fallin)
Rm 2E 614, Pentagon
Washington, DC 20301

COL Elbert W. Friday, Jr.
OUSDRE
Rm 3D 129, Pentagon
Washington, DC 20301

Defense Communications Agency
Technical Library Center
Code 222
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: Technical Library (Mrs. Betty Fox)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: RAAE (Dr. Carl Fitz)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: SPAS (Mr. Donald J. Kohler)
Washington, DC 20305

Defense Intelligence Agency
ATTN: DT/AC (LTC Robert Poplawski)
Washington, DC 20301

HQDA (DAMA-ARZ-D/Dr. Verderame)
Washington, DC 20310

HQDA (DAMI-ISP/Mr. Beck)
Washington, DC 20310

Department of the Army
Deputy Chief of Staff for
Operations and Plans
ATTN: DAMO-RQ
Washington, DC 20310

Department of the Army
Director of Telecommunications and
Command and Control
ATTN: DAMO-TCZ
Washington, DC 20310

Department of the Army
Assistant Chief of Staff for Intelligence
ATTN: DAMI-TS
Washington, DC 20310

HQDA (DAEN-RDM/Dr. de Percin)
Casimir Pulaski Building
20 Massachusetts Avenue
Room 6203
Washington, DC 20314

National Science Foundation
Division of Atmospheric Sciences
ATTN: Dr. Eugene W. Bierly
1800 G. Street, N.W.
Washington, DC 20550

Director
Naval Research Laboratory
ATTN: Code 4320 (Dr. Lothar H. Ruhnke)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6009 (Dr. John MacCallum, Jr.)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6530 (Mr. Raymond A. Patten)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6533 (Dr. James A. Dowling)
Washington, DC 20375

HQDA (DAEN-RDM/Dr. de Percin)
Casimir Pulaski Building
20 Massachusetts Avenue
Room 6203
Washington, DC 20314

National Science Foundation
Division of Atmospheric Sciences
ATTN: Dr. Eugene W. Bierly
1800 G. Street, N.W.
Washington, DC 20550

Director
Naval Research Laboratory
ATTN: Code 4320 (Dr. Lothar H. Ruhnke)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6009 (Dr. John MacCallum, Jr.)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6530 (Mr. Raymond A. Patten)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6533 (Dr. James A. Dowling)
Washington, DC 20375

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Lindberg, J.D., "An Improvement to a Method for Measuring the Absorption Coefficient of Atmospheric Dust and other Strongly Absorbing Powders," ECOM-5565, July 1975.
2. Avara, Elton, P., "Mesoscale Wind Shears Derived from Thermal Winds," ECOM-5566, July 1975.
3. Gomez, Richard B., and Joseph H. Pierluissi, "Incomplete Gamma Function Approximation for King's Strong-Line Transmittance Model," ECOM-5567, July 1975.
4. Blanco, A.J., and B.F. Engebos, "Ballistic Wind Weighting Functions for Tank Projectiles," ECOM-5568, August 1975.
5. Taylor, Fredrick J., Jack Smith, and Thomas H. Pries, "Crosswind Measurements through Pattern Recognition Techniques," ECOM-5569, July 1975.
6. Walters, D.L., "Crosswind Weighting Functions for Direct-Fire Projectiles," ECOM-5570, August 1975.
7. Duncan, Louis D., "An Improved Algorithm for the Iterated Minimal Information Solution for Remote Sounding of Temperature," ECOM-5571, August 1975.
8. Robbiani, Raymond L., "Tactical Field Demonstration of Mobile Weather Radar Set AN/TPS-41 at Fort Rucker, Alabama," ECOM-5572, August 1975.
9. Miers, B., G. Blackman, D. Langer, and N. Lorimier, "Analysis of SMS/GOES Film Data," ECOM-5573, September 1975.
10. Manquero, Carlos, Louis Duncan, and Rufus Bruce, "An Indication from Satellite Measurements of Atmospheric CO2 Variability," ECOM-5574, September 1975.
11. Petracca, Carmine, and James D. Lindberg, "Installation and Operation of an Atmospheric Particulate Collector," ECOM-5575, September 1975.
12. Avara, Elton P., and George Alexander, "Empirical Investigation of Three Iterative Methods for Inverting the Radiative Transfer Equation," ECOM-5576, October 1975.
13. Alexander, George D., "A Digital Data Acquisition Interface for the SMS Direct Readout Ground Station — Concept and Preliminary Design," ECOM-5577, October 1975.
14. Cantor, Israel, "Enhancement of Point Source Thermal Radiation Under Clouds in a Nonattenuating Medium," ECOM-5578, October 1975.
15. Norton, Colburn, and Glenn Hoidale, "The Diurnal Variation of Mixing Height by Month over White Sands Missile Range, N.M," ECOM-5579, November 1975.
16. Avara, Elton P., "On the Spectrum Analysis of Binary Data," ECOM-5580, November 1975.
17. Taylor, Fredrick J., Thomas H. Pries, and Chao-Huan Huang, "Optimal Wind Velocity Estimation," ECOM-5581, December 1975.
18. Avara, Elton P., "Some Effects of Autocorrelated and Cross-Correlated Noise on the Analysis of Variance," ECOM-5582, December 1975.
19. Gillespie, Patti S., R.L. Armstrong, and Kenneth O. White, "The Spectral Characteristics and Atmospheric CO2 Absorption of the Ho^{+3}:YLF Laser at 2.05μm," ECOM-5583, December 1975.
20. Novlan, David J. "An Empirical Method of Forecasting Thunderstorms for the White Sands Missile Range," ECOM-5584, February 1976.
21. Avara, Elton P., "Randomization Effects in Hypothesis Testing with Autocorrelated Noise," ECOM-5585, February 1976.
22. Watkins, Wendell R., "Improvements in Long Path Absorption Cell Measurement," ECOM-5586, March 1976.
23. Thomas, Joe, George D. Alexander, and Marvin Dubbin, "SATTEL — An Army Dedicated Meteorological Telemetry System," ECOM-5587, March 1976.
24. Kennedy, Bruce W., and Delbert Bynum, "Army User Test Program for the RDT&E-XM-75 Meteorological Rocket," ECOM-5588, April 1976.

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Lindberg, J.D., "An Improvement to a Method for Measuring the Absorption Coefficient of Atmospheric Dust and other Strongly Absorbing Powders," ECOM-5565, July 1975.
2. Avara, Elton, P., "Mesoscale Wind Shears Derived from Thermal Winds," ECOM-5566, July 1975.
3. Gomez, Richard B., and Joseph H. Pierluissi, "Incomplete Gamma Function Approximation for King's Strong-Line Transmittance Model," ECOM-5567, July 1975.
4. Blanco, A.J., and B.F. Engebos, "Ballistic Wind Weighting Functions for Tank Projectiles," ECOM-5568, August 1975.
5. Taylor, Fredrick J., Jack Smith, and Thomas H. Pries, "Crosswind Measurements through Pattern Recognition Techniques," ECOM-5569, July 1975.
6. Walters, D.L., "Crosswind Weighting Functions for Direct-Fire Projectiles," ECOM-5570, August 1975.
7. Duncan, Louis D., "An Improved Algorithm for the Iterated Minimal Information Solution for Remote Sounding of Temperature," ECOM-5571, August 1975.
8. Robbiani, Raymond L., "Tactical Field Demonstration of Mobile Weather Radar Set AN/TPS-41 at Fort Rucker, Alabama," ECOM-5572, August 1975.
9. Miers, B., G. Blackman, D. Langer, and N. Lorimier, "Analysis of SMS/GOES Film Data," ECOM-5573, September 1975.
10. Manquero, Carlos, Louis Duncan, and Rufus Bruce, "An Indication from Satellite Measurements of Atmospheric CO2 Variability," ECOM-5574, September 1975.
11. Petracca, Carmine, and James D. Lindberg, "Installation and Operation of an Atmospheric Particulate Collector," ECOM-5575, September 1975.
12. Avara, Elton P., and George Alexander, "Empirical Investigation of Three Iterative Methods for Inverting the Radiative Transfer Equation," ECOM-5576, October 1975.
13. Alexander, George D., "A Digital Data Acquisition Interface for the SMS Direct Readout Ground Station — Concept and Preliminary Design," ECOM-5577, October 1975.
14. Cantor, Israel, "Enhancement of Point Source Thermal Radiation Under Clouds in a Nonattenuating Medium," ECOM-5578, October 1975.
15. Norton, Colburn, and Glenn Hoidale, "The Diurnal Variation of Mixing Height by Month over White Sands Missile Range, N.M," ECOM-5579, November 1975.
16. Avara, Elton P., "On the Spectrum Analysis of Binary Data," ECOM-5580, November 1975.
17. Taylor, Fredrick J., Thomas H. Pries, and Chao-Huan Huang, "Optimal Wind Velocity Estimation," ECOM-5581, December 1975.
18. Avara, Elton P., "Some Effects of Autocorrelated and Cross-Correlated Noise on the Analysis of Variance," ECOM-5582, December 1975.
19. Gillespie, Patti S., R.L. Armstrong, and Kenneth O. White, "The Spectral Characteristics and Atmospheric CO2 Absorption of the Ho^{+3}:YLF Laser at 2.05μm," ECOM-5583, December 1975.
20. Novlan, David J. "An Empirical Method of Forecasting Thunderstorms for the White Sands Missile Range," ECOM-5584, February 1976.
21. Avara, Elton P., "Randomization Effects in Hypothesis Testing with Autocorrelated Noise," ECOM-5585, February 1976.
22. Watkins, Wendell R., "Improvements in Long Path Absorption Cell Measurement," ECOM-5586, March 1976.
23. Thomas, Joe, George D. Alexander, and Marvin Dubbin, "SATTEL — An Army Dedicated Meteorological Telemetry System," ECOM-5587, March 1976.
24. Kennedy, Bruce W., and Delbert Bynum, "Army User Test Program for the RDT&E-XM-75 Meteorological Rocket," ECOM-5588, April 1976.

25. Barnett, Kenneth M., "A Description of the Artillery Meteorological Comparisons at White Sands Missle Range, October 1974 - December 1974 ('PASS' - Prototype Artillery [Meteorological] Subsystem)," ECOM-5589, April 1976.

26. Miller, Walter B., "Preliminary Analysis of Fall-of-Shot From Project 'PASS'," ECOM-5590, April 1976.

27. Avara, Elton P., "Error Analysis of Minimum Information and Smith's Direct Methods for Inverting the Radiative Transfer Equation," ECOM-5591, April 1976.

28. Yee, Young P., James D. Horn, and George Alexander, "Synoptic Thermal Wind Calculations from Radiosonde Observations Over the Southwestern United States," ECOM-5592, May 1976.

29. Duncan, Louis D., and Mary Ann Seagraves, "Applications of Empirical Corrections to NOAA-4 VTPR Observations," ECOM-5593, May 1976.

30. Miers, Bruce T., and Steve Weaver, "Applications of Meterological Satellite Data to Weather Sensitive Army Operations,"ECOM-5594, May 1976.

31. Sharenow, Moses, "Redesign and Improvement of Balloon ML-566," ECOM-5595, June, 1976.

32. Hansen, Frank V., "The Depth of the Surface Boundary Layer," ECOM-5596, June 1976.

33. Pinnick, R.G., and E.B. Stenmark, "Response Calculations for a Commercial Light-Scattering Aerosol Counter," ECOM-5597, July 1976.

34. Mason, J., and G.B. Hoidale, "Visibility as an Estimator of Infrared Transmittance," ECOM-5598, July 1976.

35. Bruce, Rufus E., Louis D. Duncan, and Joseph H. Pierluissi, "Experimental Study of the Relationship Between Radiosonde Temperatures and Radiometric-Area Temperatures," ECOM-5599, August 1976.

36. Duncan, Louis D., "Stratospheric Wind Shear Computed from Satellite Thermal Sounder Measurements," ECOM-5800, September 1976.

37. Taylor, F., P. Mohan, P. Joseph and T. Pries, "An All Digital Automated Wind Measurement System," ECOM-5801, September 1976.

38. Bruce, Charles, "Development of Spectrophones for CW and Pulsed Radiation Sources," ECOM-5802, September 1976.

39. Duncan, Louis D., and Mary Ann Seagraves,"Another Method for Estimating Clear Column Radiances," ECOM-5803, October 1976.

40. Blanco, Abel J., and Larry E. Taylor, "Artillery Meteorological Analysis of Project Pass," ECOM-5804, October 1976.

41. Miller, Walter, and Bernard Engebos," A Mathematical Structure for Refinement of Sound Ranging Estimates," ECOM-5805, November, 1976.

42. Gillespie, James B., and James D. Lindberg, "A Method to Obtain Diffuse Reflectance Measurements from 1.0 to 3.0 μm Using a Cary 171 Spectrophotometer," ECOM-5806, November 1976.

43. Rubio, Roberto, and Robert O. Olsen,"A Study of the Effects of Temperature Variations on Radio Wave Absorption,"ECOM-5807, November 1976.

44. Ballard, Harold N., "Temperature Measurements in the Stratosphere from Balloon-Borne Instrument Platforms, 1968-1975," ECOM-5808, December 1976.

45. Monahan, H.H., "An Approach to the Short-Range Prediction of Early Morning Radiation Fog," ECOM-5809, January 1977.

46. Engebos, Bernard Francis, "Introduction to Multiple State Multiple Action Decision Theory and Its Relation to Mixing Structures," ECOM-5810, January 1977.

47. Low, Richard D.H.,"Effects of Cloud Particles on Remote Sensing from Space in the 10-Micrometer Infrared Region," ECOM-5811, January 1977.

48 Bonner, Robert S., and R. Newton, "Application of the AN/GVS-5 Laser Rangefinder to Cloud Base Height Measurements," ECOM-5812, February 1977.

49. Rubio, Roberto, "Lidar Detection of Subvisible Reentry Vehicle Erosive Atmospheric Material," ECOM-5813, March 1977.

50. Low, Richard D.H., and J.D. Horn, "Mesoscale Determination of Cloud-Top Height: Problems and Solutions," ECOM-5814, March 1977.

25. Barnett, Kenneth M., "A Description of the Artillery Meteorological Comparisons at White Sands Missle Range, October 1974 - December 1974 ('PASS' - Prototype Artillery [Meteorological] Subsystem)," ECOM-5589, April 1976.
26. Miller, Walter B., "Preliminary Analysis of Fall-of-Shot From Project 'PASS'," ECOM-5590, April 1976.
27. Avara, Elton P., "Error Analysis of Minimum Information and Smith's Direct Methods for Inverting the Radiative Transfer Equation," ECOM-5591, April 1976.
28. Yee, Young P., James D. Horn, and George Alexander, "Synoptic Thermal Wind Calculations from Radiosonde Observations Over the Southwestern United States," ECOM-5592, May 1976.
29. Duncan, Louis D., and Mary Ann Seagraves, "Applications of Empirical Corrections to NOAA-4 VTPR Observations," ECOM-5593, May 1976.
30. Miers, Bruce T., and Steve Weaver, "Applications of Meterological Satellite Data to Weather Sensitive Army Operations,"ECOM-5594, May 1976.
31. Sharenow, Moses, "Redesign and Improvement of Balloon ML-566," ECOM-5595, June, 1976.
32. Hansen, Frank V., "The Depth of the Surface Boundary Layer," ECOM-5596, June 1976.
33. Pinnick, R.G., and E.B. Stenmark, "Response Calculations for a Commercial Light-Scattering Aerosol Counter," ECOM-5597, July 1976.
34. Mason, J., and G.B. Hoidale, "Visibility as an Estimator of Infrared Transmittance," ECOM-5598, July 1976.
35. Bruce, Rufus E., Louis D. Duncan, and Joseph H. Pierluissi, "Experimental Study of the Relationship Between Radiosonde Temperatures and Radiometric-Area Temperatures," ECOM-5599, August 1976.
36. Duncan, Louis D., "Stratospheric Wind Shear Computed from Satellite Thermal Sounder Measurements," ECOM-5800, September 1976.
37. Taylor, F., P. Mohan, P. Joseph and T. Pries, "An All Digital Automated Wind Measurement System," ECOM-5801, September 1976.
38. Bruce, Charles, "Development of Spectrophones for CW and Pulsed Radiation Sources," ECOM-5802, September 1976.
39. Duncan, Louis D., and Mary Ann Seagraves,"Another Method for Estimating Clear Column Radiances," ECOM-5803, October 1976.
40. Blanco, Abel J., and Larry E. Taylor, "Artillery Meteorological Analysis of Project Pass," ECOM-5804, October 1976.
41. Miller, Walter, and Bernard Engebos," A Mathematical Structure for Refinement of Sound Ranging Estimates," ECOM-5805, November, 1976.
42. Gillespie, James B., and James D. Lindberg, "A Method to Obtain Diffuse Reflectance Measurements from 1.0 to 3.0 μm Using a Cary 171 Spectrophotometer," ECOM-5806, November 1976.
43. Rubio, Roberto, and Robert O. Olsen,"A Study of the Effects of Temperature Variations on Radio Wave Absorption,"ECOM-5807, November 1976.
44. Ballard, Harold N., "Temperature Measurements in the Stratosphere from Balloon-Borne Instrument Platforms, 1968-1975," ECOM-5808, December 1976.
45. Monahan, H.H., "An Approach to the Short-Range Prediction of Early Morning Radiation Fog," ECOM-5809, January 1977.
46. Engebos, Bernard Francis, "Introduction to Multiple State Multiple Action Decision Theory and Its Relation to Mixing Structures," ECOM-5810, January 1977.
47. Low, Richard D.H.,"Effects of Cloud Particles on Remote Sensing from Space in the 10-Micrometer Infrared Region," ECOM-5811, January 1977.
48 Bonner, Robert S., and R. Newton, "Application of the AN/GVS-5 Laser Rangefinder to Cloud Base Height Measurements," ECOM-5812, February 1977.
49. Rubio, Roberto, "Lidar Detection of Subvisible Reentry Vehicle Erosive Atmospheric Material," ECOM-5813, March 1977.
50. Low, Richard D.H., and J.D. Horn, "Mesoscale Determination of Cloud-Top Height: Problems and Solutions," ECOM-5814, March 1977.

51. Duncan, Louis D., and Mary Ann Seagraves,"Evaluation of the NOAA-4 VTPR Thermal Winds for Nuclear Fallout Predictions," ECOM-5815, March 1977.
52. Randhawa, Jagir S., M. Izquierdo, Carlos McDonald and Zvi Salpeter, "Stratospheric Ozone Density as Measured by a Chemiluminescent Sensor During the Stratcom VI-A Flight," ECOM-5816, April 1977.
53. Rubio, Roberto, and Mike Izquierdo, "Measurements of Net Atmospheric Irradiance in the 0.7- to 2.8-Micrometer Infrared Region," ECOM-5817, May 1977.
54. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson Consultant for Chemical Kinetics, "Calculation of Selected Atmospheric Composition Parameters for the Mid-Latitude, September Stratosphere," ECOM-5818, May 1977.
55. Mitchell, J.D., R.S. Sagar, and R.O. Olsen, "Positive Ions in the Middle Atmosphere During Sunrise Conditions," ECOM-5819, May 1977.
56. White, Kenneth O., Wendell R. Watkins, Stuart A. Schleusener, and Ronald L. Johnson, "Solid-State Laser Wavelength Identification Using a Reference Absorber," ECOM-5820, June 1977.
57. Watkins, Wendell R., and Richard G. Dixon, "Automation of Long-Path Absorption Cell Measurements," ECOM-5821, June 1977.
58. Taylor, S.E., J.M. Davis, and J.B. Mason, "Analysis of Observed Soil Skin Moisture Effects on Reflectance," ECOM-5822, June 1977.
59. Duncan, Louis D. and Mary Ann Seagraves, "Fallout Predictions Computed from Satellite Derived Winds," ECOM-5823, June 1977.
60. Snider, D.E., D.G. Murcray, F.H. Murcray, and W.J. Williams, "Investigation of High-Altitude Enhanced Infrared Backround Emissions" (U), SECRET, ECOM-5824, June 1977.
61. Dubbin, Marvin H. and Dennis Hall, "Synchronous Meteorlogical Satellite Direct *Readout Ground* System Digital Video Electronics," ECOM-5825, June 1977.
62. Miller, W., and B. Engebos, "A Preliminary Analysis of Two Sound Ranging Algorithms," ECOM-5826, July 1977.
63. Kennedy, Bruce W., and James K. Luers, "Ballistic Sphere Techniques for Measuring Atomspheric Parameters," ECOM-5827, July 1977
64. Duncan, Louis D., "Zenith Angle Variation of Satellite Thermal Sounder Measurements," ECOM-5828, August 1977.
65. Hansen, Frank V., "The Critical Richardson Number," ECOM-5829, September 1977.
66. Ballard, Harold N., and Frank P. Hudson (Compilers), "Stratospheric Composition Balloon-Borne Experiment," ECOM-5830, October 1977.
67. Barr, William C., and Arnold C. Peterson, "Wind Measuring Accuracy Test of Meteorological Systems," ECOM-5831, November 1977.
68. Ethridge, G.A. and F.V. Hansen, "Atmospheric Diffusion: Similarity Theory and Empirical Derivations for Use in Boundary Layer Diffusion Problems," ECOM-5832, November 1977.
69. Low, Richard D.H., "The Internal Cloud Radiation Field and a Technique for Determining Cloud Blackness," ECOM-5833, December 1977.
70. Watkins, Wendell R., Kenneth O. White, Charles W. Bruce, Donald L. Walters, and James D. Lindberg, "Measurements Required for Prediction of High Energy Laser Transmission," ECOM-5834, December 1977.
71. Rubio, Robert, "Investigation of Abrupt Decreases in Atmospherically Backscattered Laser Energy," ECOM-5835, December 1977.
72. Monahan, H.H. and R.M. Cionco, "An Interpretative Review of Existing Capabilities for Measuring and Forecasting Selected Weather Variables (Emphasizing Remote Means)," ASL-TR-0001, January 1978.
73. Heaps, Melvin G., "The 1979 Solar Eclipse and Validation of D Region Models," ASL-TR-0002, March 1978.

51. Duncan, Louis D., and Mary Ann Seagraves,"Evaluation of the NOAA-4 VTPR Thermal Winds for Nuclear Fallout Predictions," ECOM-5815, March 1977.

52. Randhawa, Jagir S., M. Izquierdo, Carlos McDonald and Zvi Salpeter, "Stratospheric Ozone Density as Measured by a Chemiluminescent Sensor During the Stratcom VI-A Flight," ECOM-5816, April 1977.

53. Rubio, Roberto, and Mike Izquierdo, "Measurements of Net Atmospheric Irradiance in the 0.7- to 2.8-Micrometer Infrared Region," ECOM-5817, May 1977.

54. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson Consultant for Chemical Kinetics, "Calculation of Selected Atmospheric Composition Parameters for the Mid-Latitude, September Stratosphere," ECOM-5818, May 1977.

55. Mitchell, J.D., R.S. Sagar, and R.O. Olsen, "Positive Ions in the Middle Atmosphere During Sunrise Conditions," ECOM-5819, May 1977.

56. White, Kenneth O., Wendell R. Watkins, Stuart A. Schleusener, and Ronald L. Johnson, "Solid-State Laser Wavelength Identification Using a Reference Absorber," ECOM-5820, June 1977.

57. Watkins, Wendell R., and Richard G. Dixon, "Automation of Long-Path Absorption Cell Measurements," ECOM-5821, June 1977.

58. Taylor, S.E., J.M. Davis, and J.B. Mason, "Analysis of Observed Soil Skin Moisture Effects on Reflectance," ECOM-5822, June 1977.

59. Duncan, Louis D. and Mary Ann Seagraves, "Fallout Predictions Computed from Satellite Derived Winds," ECOM-5823, June 1977.

60. Snider, D.E., D.G. Murcray, F.H. Murcray, and W.J. Williams, "Investigation of High-Altitude Enhanced Infrared Backround Emissions" (U), SECRET, ECOM-5824, June 1977.

61. Dubbin, Marvin H. and Dennis Hall, "Synchronous Meteorlogical Satellite Direct *Readout Ground* System Digital Video Electronics," ECOM-5825, June 1977.

62. Miller, W., and B. Engebos, "A Preliminary Analysis of Two Sound Ranging Algorithms," ECOM-5826, July 1977.

63. Kennedy, Bruce W., and James K. Luers, "Ballistic Sphere Techniques for Measuring Atomspheric Parameters," ECOM-5827, July 1977

64. Duncan, Louis D., "Zenith Angle Variation of Satellite Thermal Sounder Measurements," ECOM-5828, August 1977.

65. Hansen, Frank V., "The Critical Richardson Number," ECOM-5829, September 1977.

66. Ballard, Harold N., and Frank P. Hudson (Compilers), "Stratospheric Composition Balloon-Borne Experiment," ECOM-5830, October 1977.

67. Barr, William C., and Arnold C. Peterson, "Wind Measuring Accuracy Test of Meteorological Systems," ECOM-5831, November 1977.

68. Ethridge, G.A. and F.V. Hansen, "Atmospheric Diffusion: Similarity Theory and Empirical Derivations for Use in Boundary Layer Diffusion Problems," ECOM-5832, November 1977.

69. Low, Richard D.H., "The Internal Cloud Radiation Field and a Technique for Determining Cloud Blackness," ECOM-5833, December 1977.

70. Watkins, Wendell R., Kenneth O. White, Charles W. Bruce, Donald L. Walters, and James D. Lindberg, "Measurements Required for Prediction of High Energy Laser Transmission," ECOM-5834, December 1977.

71. Rubio, Robert, "Investigation of Abrupt Decreases in Atmospherically Backscattered Laser Energy," ECOM-5835, December 1977.

72. Monahan, H.H. and R.M. Cionco, "An Interpretative Review of Existing Capabilities for Measuring and Forecasting Selected Weather Variables (Emphasizing Remote Means)," ASL-TR-0001, January 1978.

73. Heaps, Melvin G., "The 1979 Solar Eclipse and Validation of D Region Models," ASL-TR-0002, March 1978.

74. Jennings, S.G., and J.B. Gillespie, "M.I.E. Theory Sensitivity Studies - The Effects of Aerosol Complex Refractive Index and Size Distribution Variations on Extinction and Absorption Coefficients Part II: Analysis of the Computational Results," ASL-TR-0003, March 1978.
75. White, Kenneth O. et al, "Water Vapor Continuum Absorption in the 3.5μm to 4.0μm Region," ASL-TR-0004, March 1978.
76. Olsen, Robert O., and Bruce W. Kennedy, "ABRES Pretest Atmospheric Measurements," ASL-TR-0005, April 1978.
77. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson, "Calculation of Atmospheric Composition in the High Latitude September Stratosphere," ASL-TR-0006, May 1978.
78. Watkins, Wendell R. et al, "Water Vapor Absorption Coefficients at HF Laser Wavelengths," ASL-TR-0007, May 1978.
79. Hansen, Frank V., "The Growth and Prediction of Nocturnal Inversions," ASL-TR-0008, May 1978.
80. Samuel, Christine, Charles Bruce, and Ralph Brewer, "Spectrophone Analysis of Gas Samples Obtained at Field Site," ASL-TR-0009, June 1978.
81. Pinnick, R.G. et al., "Vertical Structure in Atmospheric Fog and Haze and its Effects on IR Extinction," ASL-TR-0010, July 1978.
82. Low, Richard D.H., Louis D. Duncan, and Richard B. Gomez, "The Microphysical Basis of Fog Optical Characterization," ASL-TR-0011, August 1978.
83. Heaps, Melvin G., "The Effect of a Solar Proton Event on the Minor Neutral Constituents of the Summer Polar Mesosphere," ASL-TR-0012, August 1978.
84. Mason, James B., "Light Attenuation in Falling Snow," ASL-TR-0013, August 1978.
85. Blanco, Abel J., "Long-Range Artillery Sound Ranging: "PASS" Meteorological Application," ASL-TR-0014, September 1978.
86. Heaps, M.G., and F.E. Niles, "Modeling the Ion Chemistry of the D-Region: A case Study Based Upon the 1966 Total Solar Eclipse," ASL-TR-0015, September 1978.
87. Jennings, S.G., and R.G. Pinnick, "Effects of Particulate Complex Refractive Index and Particle Size Distribution Variations on Atmospheric Extinction and Absorption for Visible Through Middle-Infrared Wavelengths," ASL-TR-0016, September 1978.
88. Watkins, Wendell R., Kenneth O. White, Lanny R. Bower, and Brian Z. Sojka, " Pressure Dependence of the Water Vapor Continuum Absorption in the 3.5- to 4.0-Micrometer Region," ASL-TR-0017, September 1978.
89. Miller, W.B., and B.F. Engebos, "Behavior of Four Sound Ranging Techniques in an Idealized Physical Environment," ASL-TR-0018, September 1978.
90. Gomez, Richard G., "Effectiveness Studies of the CBU-88/B Bomb, Cluster, Smoke Weapon" (U), CONFIDENTIAL ASL-TR-0019, September 1978.
91. Miller, August, Richard C. Shirkey, and Mary Ann Seagraves, "Calculation of Thermal Emission from Aerosols Using the Doubling Technique," ASL-TR-0020, November, 1978.
92. Lindberg, James D. et al., "Measured Effects of Battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelengths Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I)," ASL-TR-0021, January 1979.
93. Kennedy, Bruce W., Arthur Kinghorn, and B.R. Hixon, "Engineering Flight Tests of Range Meteorological Sounding System Radiosonde," ASL-TR-0022, February 1979.
94. Rubio, Roberto, and Don Hoock, "Microwave Effective Earth Radius Factor Variability at Wiesbaden and Balboa," ASL-TR-0023, February 1979.
95. Low, Richard D.H., "A Theoretical Investigation of Cloud/Fog Optical Properties and Their Spectral Correlations," ASL-TR-0024, February 1979.

74. Jennings, S.G., and J.B. Gillespie, "M.I.E. Theory Sensitivity Studies - The Effects of Aerosol Complex Refractive Index and Size Distribution Variations on Extinction and Absorption Coefficients Part II: Analysis of the Computational Results," ASL-TR-0003, March 1978.

75. White, Kenneth O. et al, "Water Vapor Continuum Absorption in the 3.5μm to 4.0μm Region," ASL-TR-0004, March 1978.

76. Olsen, Robert O., and Bruce W. Kennedy, "ABRES Pretest Atmospheric Measurements," ASL-TR-0005, April 1978.

77. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson, "Calculation of Atmospheric Composition in the High Latitude September Stratosphere," ASL-TR-0006, May 1978.

78. Watkins, Wendell R. et al, "Water Vapor Absorption Coefficients at HF Laser Wavelengths," ASL-TR-0007, May 1978.

79. Hansen, Frank V., "The Growth and Prediction of Nocturnal Inversions," ASL-TR-0008, May 1978.

80. Samuel, Christine, Charles Bruce, and Ralph Brewer, "Spectrophone Analysis of Gas Samples Obtained at Field Site," ASL-TR-0009, June 1978.

81. Pinnick, R.G. et al., "Vertical Structure in Atmospheric Fog and Haze and its Effects on IR Extinction," ASL-TR-0010, July 1978.

82. Low, Richard D.H., Louis D. Duncan, and Richard B. Gomez, "The Microphysical Basis of Fog Optical Characterization," ASL-TR-0011, August 1978.

83. Heaps, Melvin G., "The Effect of a Solar Proton Event on the Minor Neutral Constituents of the Summer Polar Mesosphere," ASL-TR-0012, August 1978.

84. Mason, James B., "Light Attenuation in Falling Snow," ASL-TR-0013, August 1978.

85. Blanco, Abel J., "Long-Range Artillery Sound Ranging: "PASS" Meteorological Application," ASL-TR-0014, September 1978.

86. Heaps, M.G., and F.E. Niles, "Modeling the Ion Chemistry of the D-Region: A case Study Based Upon the 1966 Total Solar Eclipse," ASL-TR-0015, September 1978.

87. Jennings, S.G., and R.G. Pinnick, "Effects of Particulate Complex Refractive Index and Particle Size Distribution Variations on Atmospheric Extinction and Absorption for Visible Through Middle-Infrared Wavelengths," ASL-TR-0016, September 1978.

88. Watkins, Wendell R., Kenneth O. White, Lanny R. Bower, and Brian Z. Sojka, "Pressure Dependence of the Water Vapor Continuum Absorption in the 3.5- to 4.0-Micrometer Region," ASL-TR-0017, September 1978.

89. Miller, W.B., and B.F. Engebos, "Behavior of Four Sound Ranging Techniques in an Idealized Physical Environment," ASL-TR-0018, September 1978.

90. Gomez, Richard G., "Effectiveness Studies of the CBU-88/B Bomb, Cluster, Smoke Weapon" (U), CONFIDENTIAL ASL-TR-0019, September 1978.

91. Miller, August, Richard C. Shirkey, and Mary Ann Seagraves, "Calculation of Thermal Emission from Aerosols Using the Doubling Technique," ASL-TR-0020, November, 1978.

92. Lindberg, James D. et al., "Measured Effects of Battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelengths Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I)," ASL-TR-0021, January 1979.

93. Kennedy, Bruce W., Arthur Kinghorn, and B.R. Hixon, "Engineering Flight Tests of Range Meteorological Sounding System Radiosonde," ASL-TR-0022, February 1979.

94. Rubio, Roberto, and Don Hoock, "Microwave Effective Earth Radius Factor Variability at Wiesbaden and Balboa," ASL-TR-0023, February 1979.

95. Low, Richard D.H., "A Theoretical Investigation of Cloud/Fog Optical Properties and Their Spectral Correlations," ASL-TR-0024, February 1979.

96. Pinnick, R.G., and H.J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," ASL-TR-0025, February 1979.
97. Heaps, Melvin G., Robert O. Olsen, and Warren W. Berning, "Solar Eclipse 1979, Atmospheric Sciences Laboratory Program Overview," ASL-TR-0026 February 1979.
98. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' GR-8 Sound Ranging Data," ASL-TR-0027, March 1979.
99. Kennedy, Bruce W., and Jose M. Serna, "Meteorological Rocket Network System Reliability," ASL-TR-0028, March 1979.
100. Swingle, Donald M., "Effects of Arrival Time Errors in Weighted Range Equation Solutions for Linear Base Sound Ranging," ASL-TR-0029, April 1979.
101. Umstead, Robert K., Ricardo Pena, and Frank V. Hansen, "KWIK: An Algorithm for Calculating Munition Expenditures for Smoke Screening/Obscuration in Tactical Situations," ASL-TR-0030, April 1979.
102. D'Arcy, Edward M., "Accuracy Validation of the Modified Nike Hercules Radar," ASL-TR-0031, May 1979.
103. Rodriguez, Ruben, "Evaluation of the Passive Remote Crosswind Sensor," ASL-TR-0032, May 1979.
104. Barber, T.L., and R. Rodgriquez, "Transit Time Lidar Measurement of Near-Surface Winds in the Atmosphere," ASL-TR-0033, May 1979.
105. Low, Richard D.H., Louis D. Duncan, and Y.Y. Roger R. Hsiao, "Microphysical and Optical Properties of California Coastal Fogs at Fort Ord," ASL-TR-0034, June 1979.
106. Rodriguez, Ruben, and William J. Vechione, "Evaluation of the Saturation Resistant Crosswind Sensor," ASL-TR-0035, July 1979.
107. Ohmstede, William D., "The Dynamics of Material Layers," ASL-TR-0036, July 1979.
108. Pinnick, R.G., S.G. Jennings, Petr Chylek, and H.J. Auvermann "Relationships between IR Extinction, Absorption, and Liquid Water Content of Fogs," ASL-TR-0037, August 1979.
109. Rodriguez, Ruben, and William J. Vechione, "Performance Evaluation of the Optical Crosswind Profiler," ASL-TR-0038, August 1979.
110. Miers, Bruce T., "Precipitation Estimation Using Satellite Data" ASL-TR-0039, September 1979.
111. Dickson, David H., and Charles M. Sonnenschein, "Helicopter Remote Wind Sensor System Description," ASL-TR-0040, September 1979.
112. Heaps, Melvin, G., and Joseph M. Heimerl, "Validation of the Dairchem Code, I: Quiet Midlatitude Conditions," ASL-TR-0041, September 1979.
113. Bonner, Robert S., and William J. Lentz, "The Visioceilometer: A Portable Cloud Height and Visibility Indicator," ASL-TR-0042, October 1979.
114. Cohn, Stephen L., "The Role of Atmospheric Sulfates in Battlefield Obscurations," ASL-TR-0043, October 1979.
115. Fawbush, E.J. et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range, New Mexico, Part I, 24 March to 8 April 1977," ASL-TR-0044, November 1979
116. Barber, Ted L., "Short-Time Mass Variation in Natural Atmospheric Dust," ASL-TR-0045, November 1979
117. Low, Richard D.H., "Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling," ASL-TR-0046, December 1979
118. Duncan, Louis D. et al, "The Electro-Optical Systems Atmospheric Effects Library, Volume I: Technical Documentation, ASL-TR-0047, December 1979.
119. Shirkey, R. C. et al, "Interim E-O SAEL, Volume II, Users Manual," ASL-TR-0048, December 1979.
120. Kobayashi, H.K., "Atmospheric Effects on Millimeter Radio Waves," ASL-TR-0049, January 1980.
121. Seagraves, Mary Ann and Duncan, Louis D., "An Analysis of Transmittances Measured Through Battlefield Dust Clouds," ASL-TR-0050, February, 1980.

96. Pinnick, R.G., and H.J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," ASL-TR-0025, February 1979.
97. Heaps, Melvin G., Robert O. Olsen, and Warren W. Berning, "Solar Eclipse 1979, Atmospheric Sciences Laboratory Program Overview," ASL-TR-0026 February 1979.
98. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' GR-8 Sound Ranging Data," ASL-TR-0027, March 1979.
99. Kennedy, Bruce W., and Jose M. Serna, "Meteorological Rocket Network System Reliability," ASL-TR-0028, March 1979.
100. Swingle, Donald M., "Effects of Arrival Time Errors in Weighted Range Equation Solutions for Linear Base Sound Ranging," ASL-TR-0029, April 1979.
101. Umstead, Robert K., Ricardo Pena, and Frank V. Hansen, "KWIK: An Algorithm for Calculating Munition Expenditures for Smoke Screening/Obscuration in Tactical Situations," ASL-TR-0030, April 1979.
102. D'Arcy, Edward M., "Accuracy Validation of the Modified Nike Hercules Radar," ASL-TR-0031, May 1979.
103. Rodriguez, Ruben, "Evaluation of the Passive Remote Crosswind Sensor," ASL-TR-0032, May 1979.
104. Barber, T.L., and R. Rodgriquez, "Transit Time Lidar Measurement of Near-Surface Winds in the Atmosphere," ASL-TR-0033, May 1979.
105. Low, Richard D.H., Louis D. Duncan, and Y.Y. Roger R. Hsiao, "Microphysical and Optical Properties of California Coastal Fogs at Fort Ord," ASL-TR-0034, June 1979.
106. Rodriguez, Ruben, and William J. Vechione, "Evaluation of the Saturation Resistant Crosswind Sensor," ASL-TR-0035, July 1979.
107. Ohmstede, William D., "The Dynamics of Material Layers," ASL-TR-0036, July 1979.
108. Pinnick, R.G., S.G. Jennings, Petr Chylek, and H.J. Auvermann "Relationships between IR Extinction, Absorption, and Liquid Water Content of Fogs," ASL-TR-0037, August 1979.
109. Rodriguez, Ruben, and William J. Vechione, "Performance Evaluation of the Optical Crosswind Profiler," ASL-TR-0038, August 1979.
110. Miers, Bruce T., "Precipitation Estimation Using Satellite Data" ASL-TR-0039, September 1979.
111. Dickson, David H., and Charles M. Sonnenschein, "Helicopter Remote Wind Sensor System Description," ASL-TR-0040, September 1979.
112. Heaps, Melvin, G., and Joseph M. Heimerl, "Validation of the Dairchem Code, I: Quiet Midlatitude Conditions," ASL-TR-0041, September 1979.
113. Bonner, Robert S., and William J. Lentz, "The Visioceilometer: A Portable Cloud Height and Visibility Indicator," ASL-TR-0042, October 1979.
114. Cohn, Stephen L., "The Role of Atmospheric Sulfates in Battlefield Obscurations," ASL-TR-0043, October 1979.
115. Fawbush, E.J. et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range, New Mexico, Part I, 24 March to 8 April 1977," ASL-TR-0044, November 1979
116. Barber, Ted L., "Short-Time Mass Variation in Natural Atmospheric Dust," ASL-TR-0045, November 1979
117. Low, Richard D.H., "Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling," ASL-TR-0046, December 1979
118. Duncan, Louis D. et al, "The Electro-Optical Systems Atmospheric Effects Library, Volume I: Technical Documentation, ASL-TR-0047, December 1979.
119. Shirkey, R. C. et al, "Interim E-O SAEL, Volume II, Users Manual," ASL-TR-0048, December 1979.
120. Kobayashi, H.K., "Atmospheric Effects on Millimeter Radio Waves," ASL-TR-0049, January 1980.
121. Seagraves, Mary Ann and Duncan, Louis D., "An Analysis of Transmittances Measured Through Battlefield Dust Clouds," ASL-TR-0050, February, 1980.

122. Dickson, David H., and Jon E. Ottesen, "Helicopter Remote Wind Sensor Flight Test," ASL-TR-0051, February 1980.

123. Pinnick, R. G., and S. G. Jennings, "Relationships Between Radiative Properties and Mass Content of Phosphoric Acid, HC, Petroleum Oil, and Sulfuric Acid Military Smokes," ASL-TR-0052, April 1980.

124. Hinds, B. D., and J. B. Gillespie, "Optical Characterization of Atmospheric Particulates on San Nicolas Island, California," ASL-TR-0053, April 1980.

125. Miers, Bruce T.,"Precipitation Estimation for Military Hydrology,"ASL-TR-0054, April 1980.

126. Stenmark, Ernest B., "Objective Quality Control of Artillery Computer Meteorological Messages," ASL-TR-0055, April 1980.

127. Duncan, Louis D., and Richard D. H. Low, "Bimodal Size Distribution Models for Fogs at Meppen, Germany, " ASL-TR-0056, April 1980.

128. Olsen, Robert O., and Jagir S. Randhawa, "The Influence of Atmospheric Dynamics on Ozone and Temperature Structure," ASL-TR-0057, May 1980.

129. Kennedy, Bruce W., et al, "Dusty Infrared Test-II (DIRT-II) Program," ASL-TR-0058, May 1980.

130. Heaps, Melvin G., Roberts O. Olsen, Warren Berning, John Cross, and Arthur Gilcrease, "1979 Solar Eclipse,Part I - Atmospheric Sciences Laboratory Field Program Summary," ASL-TR-0059, May 1980.

131. Miller, Walter B.,"User's Guide for Passive Target Acquisition Program Two (PTAP-2)," ASL-TR-0060, June 1980.

132. Holt, E. H., editor, "Atmospheric Data Requirements for Battlefield Obscuration Applications, " ASL-TR-0061, June 1980.

133. Shirkey, Richard C., August Miller, George H. Goeaecke, and Yugal Behl, "Single Scattering Code AGAUSX: Theory, Applications, Comparisons, and Listing," ASL—TR-0062, July 1980.

134. Sojka, Brain Z., and Kenneth O. White, "Evaluation of Specialized Photoacoustic Absorption Chambers for Near-millimeter Wave (NMMW) Propagation Measurements," ASL-TR-0063, August 1980.

135. Bruce, Charles W., Young Paul Yee, and S. G. Jennings, "In Situ Measurement of the Ratio of Aerosol Absorption to Extinction Coefficient," ASL-TR-0064, August 1980.

136. Yee, Young Paul, Charles W. Bruce, and Ralph J. Brewer, "Gaseous/Particulate Absorption Studies at WSMR using Laser Sourced Spectrophones," ASL-TR-0065, June 1980.

137. Lindberg, James D., Radon B. Loveland, Melvin Heaps, James B. Gillespie, and Andrew F.Lewis,"Battlefield Dust and Atmospheric Characterization Measurements During West German Summertime Conditions in Support of Grafenwohr Tests," ASL-TR-0066, September 1980.

138. Vechione, W. J., "Evaluation of the Environmental Instruments, Incorporated Series 200 Dual Component Wind Set," ASL-TR-0067, September 1980.

139. Bruce, C. W., Y. P. Yee, B. D. Hinds, R. G. Pinnick, R. J. Brewer, and J. Minjares, "Initial Field Measurements of Atmospheric Absorption at 9μM to 11μM Wavelengths, " ASL-TR-0068, October 1980.

140. Heaps, M. G., R. O. Olsen, K. D. Baker, D. A. Burt, L. C. Howlett, L. L. Jensen, E. F. Pound, and G. D. Allred, "1979 Solar Eclipse: Part II Initial Results for Ionization Sources, Electron Density, and Minor Neutral Constituents," ASL-TR-0069, October 1980.

141. Low, Richard D. H., "One-Dimensional Cloud Microphysical Models for Central Europe and their Optical Properties," ASL-TR-0070, October 1980.

142. Duncan, Louis D., James D. Lindberg, and Radon B. Loveland, "An Empirical Model of the Vertical Structure of German Fogs," ASL-TR-0071, November 1980.

122. Dickson, David H., and Jon E. Ottesen, "Helicopter Remote Wind Sensor Flight Test," ASL-TR-0051, February 1980.

123. Pinnick, R. G., and S. G. Jennings, "Relationships Between Radiative Properties and Mass Content of Phosphoric Acid, HC, Petroleum Oil, and Sulfuric Acid Military Smokes," ASL-TR-0052, April 1980.

124. Hinds, B. D., and J. B. Gillespie, "Optical Characterization of Atmospheric Particulates on San Nicolas Island, California," ASL-TR-0053, April 1980.

125. Miers, Bruce T., "Precipitation Estimation for Military Hydrology," ASL-TR-0054, April 1980.

126. Stenmark, Ernest B., "Objective Quality Control of Artillery Computer Meteorological Messages," ASL-TR-0055, April 1980.

127. Duncan, Louis D., and Richard D. H. Low, "Bimodal Size Distribution Models for Fogs at Meppen, Germany," ASL-TR-0056, April 1980.

128. Olsen, Robert O., and Jagir S. Randhawa, "The Influence of Atmospheric Dynamics on Ozone and Temperature Structure," ASL-TR-0057, May 1980.

129. Kennedy, Bruce W., et al, "Dusty Infrared Test-II (DIRT-II) Program," ASL-TR-0058, May 1980.

130. Heaps, Melvin G., Roberts O. Olsen, Warren Berning, John Cross, and Arthur Gilcrease, "1979 Solar Eclipse, Part I - Atmospheric Sciences Laboratory Field Program Summary," ASL-TR-0059, May 1980.

131. Miller, Walter B., "User's Guide for Passive Target Acquisition Program Two (PTAP-2)," ASL-TR-0060, June 1980.

132. Holt, E. H., editor, "Atmospheric Data Requirements for Battlefield Obscuration Applications," ASL-TR-0061, June 1980.

133. Shirkey, Richard C., August Miller, George H. Goeaecke, and Yugal Behl, "Single Scattering Code AGAUSX: Theory, Applications, Comparisons, and Listing," ASL—TR-0062, July 1980.

134. Sojka, Brain Z., and Kenneth O. White, "Evaluation of Specialized Photoacoustic Absorption Chambers for Near-millimeter Wave (NMMW) Propagation Measurements," ASL-TR-0063, August 1980.

135. Bruce, Charles W., Young Paul Yee, and S. G. Jennings, "In Situ Measurement of the Ratio of Aerosol Absorption to Extinction Coefficient," ASL-TR-0064, August 1980.

136. Yee, Young Paul, Charles W. Bruce, and Ralph J. Brewer, "Gaseous/Particulate Absorption Studies at WSMR using Laser Sourced Spectrophones," ASL-TR-0065, June 1980.

137. Lindberg, James D., Radon B. Loveland, Melvin Heaps, James B. Gillespie, and Andrew F. Lewis, "Battlefield Dust and Atmospheric Characterization Measurements During West German Summertime Conditions in Support of Grafenwohr Tests," ASL-TR-0066, September 1980.

138. Vechione, W. J., "Evaluation of the Environmental Instruments, Incorporated Series 200 Dual Component Wind Set," ASL-TR-0067, September 1980.

139. Bruce, C. W., Y. P. Yee, B. D. Hinds, R. G. Pinnick, R. J. Brewer, and J. Minjares, "Initial Field Measurements of Atmospheric Absorption at 9μM to 11μM Wavelengths," ASL-TR-0068, October 1980.

140. Heaps, M. G., R. O. Olsen, K. D. Baker, D. A. Burt, L. C. Howlett, L. L. Jensen, E. F. Pound, and G. D. Allred, "1979 Solar Eclipse: Part II Initial Results for Ionization Sources, Electron Density, and Minor Neutral Constituents," ASL-TR-0069, October 1980.

141. Low, Richard D. H., "One-Dimensional Cloud Microphysical Models for Central Europe and their Optical Properties," ASL-TR-0070, October 1980.

142. Duncan, Louis D., James D. Lindberg, and Radon B. Loveland, "An Empirical Model of the Vertical Structure of German Fogs," ASL-TR-0071, November 1980.

143. Duncan, Louis D., 1981, "EOSAEL 80, Volume I, Technical Documentation," ASL-TR-0072, January 1981.

144. Shirkey, R. C., and S. G. O'Brien, "EOSAEL 80, Volume II, Users manual," ASL-TR-0073, January 1981.

145. Bruce, C. W., "Characterization of Aerosol Nonlinear Effects on a High-Power CO_2 Laser Beam," ASL-TR-0074 (Draft), February 1981.

146. Duncan, Louis D., and James D. Lindberg, "Air Mass Considerations in Fog Optical Modeling," ASL-TR-0075, February 1981.

147. Kunkel, Kenneth E., "Evaluation of a Tethered Kite Anemometer," ASL-TR-0076, February 1981.

148. Kunkel, K. E. et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF) White Sands Missile Range, New Mexico, August 1977 to October 1978, Part II, Optical Turbulence, Wind, Water Vapor Pressure, Temperature," ASL-TR-0077, February 1981.

149. Miers, Bruce T., "Weather Scenarios for Central Germany," ASL-TR-0078, February 1981.

150. Cogan, James L., "Sensitivity Analysis of a Mesoscale Moisture Model," ASL-TR-0079, March 1981.

151. Brewer, R. J., C. W. Bruce, and J. L. Mater, "Optoacoustic Spectroscopy of C^2H^4 at the 9μM and 10μM $C^{12}O_2{}^{16}$ Laser Wavelengths," ASL-TR-0080, March 1981.

152. Swingle, Donald M., "Reducible Errors in the Artillery Sound Ranging Solution, Part I: The Curvature Correction" (U), SECRET, ASL-TR-0081, April 1981.

153. Miller, Walter B., "The Existence and Implications of a Fundamental System of Linear Equations in Sound Ranging" (U), SECRET, ASL-TR-0082, April 1981.

154. Bruce, Dorothy, Charles W. Bruce, and Young Paul Yee, "Experimentally Determined Relationship Between Extinction and Liquid Water Content," ASL-TR-0083, April 1981.

155. Seagraves, Mary Ann, "Visible and Infrared Obscuration Effects of Ice Fog," ASL-TR-0084, May 1981.

156. Watkins, Wendell R., and Kenneth O. White, "Wedge Absorption Remote Sensor," ASL-TR-0085, May 1981.

157. Watkins, Wendell R., Kenneth O. White, and Laura J. Crow, "Turbulence Effects on Open Air Multipaths," ASL-TR-0086, May 1981.

158. Blanco, Abel J., "Extending Application of the Artillery Computer Meteorological Message," ASL-TR-0087, May 1981.

159. Heaps, M. G., D. W. Hoock, R. O. Olsen, B. F. Engebos, and R. Rubio, "High Frequency Position Location: An Assessment of Limitations and Potential Improvements," ASL-TR-0088, May 1981.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-0-777-026/28

143. Duncan, Louis D., 1981, "EOSAEL 80, Volume I, Technical Documentation," ASL-TR-0072, January 1981.
144. Shirkey, R. C., and S. G. O'Brien, "EOSAEL 80, Volume II, Users manual," ASL-TR-0073, January 1981.
145. Bruce, C. W., "Characterization of Aerosol Nonlinear Effects on a High-Power CO_2 Laser Beam," ASL-TR-0074 (Draft), February 1981.
146. Duncan, Louis D., and James D. Lindberg, "Air Mass Considerations in Fog Optical Modeling," ASL-TR-0075, February 1981.
147. Kunkel, Kenneth E., "Evaluation of a Tethered Kite Anemometer," ASL-TR-0076, February 1981.
148. Kunkel, K. E. et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF) White Sands Missile Range, New Mexico, August 1977 to October 1978, Part II, Optical Turbulence, Wind, Water Vapor Pressure, Temperature," ASL-TR-0077, February 1981.
149. Miers, Bruce T., "Weather Scenarios for Central Germany," ASL-TR-0078, February 1981.
150. Cogan, James L., "Sensitivity Analysis of a Mesoscale Moisture Model," ASL-TR-0079, March 1981.
151. Brewer, R. J., C. W. Bruce, and J. L. Mater, "Optoacoustic Spectroscopy of C^2H^4 at the $9\mu M$ and $10\mu M$ $C^{12}O_2{}^{16}$ Laser Wavelengths," ASL-TR-0080, March 1981.
152. Swingle, Donald M., "Reducible Errors in the Artillery Sound Ranging Solution, Part I: The Curvature Correction" (U), SECRET, ASL-TR-0081, April 1981.
153. Miller, Walter B., "The Existence and Implications of a Fundamental System of Linear Equations in Sound Ranging" (U), SECRET, ASL-TR-0082, April 1981.
154. Bruce, Dorothy, Charles W. Bruce, and Young Paul Yee, "Experimentally Determined Relationship Between Extinction and Liquid Water Content," ASL-TR-0083, April 1981.
155. Seagraves, Mary Ann, "Visible and Infrared Obscuration Effects of Ice Fog," ASL-TR-0084, May 1981.
156. Watkins, Wendell R., and Kenneth O. White, "Wedge Absorption Remote Sensor," ASL-TR-0085, May 1981.
157. Watkins, Wendell R., Kenneth O. White, and Laura J. Crow, "Turbulence Effects on Open Air Multipaths," ASL-TR-0086, May 1981.
158. Blanco, Abel J., "Extending Application of the Artillery Computer Meteorological Message," ASL-TR-0087, May 1981.
159. Heaps, M. G., D. W. Hoock, R. O. Olsen, B. F. Engebos, and R. Rubio, "High Frequency Position Location: An Assessment of Limitations and Potential Improvements," ASL-TR-0088, May 1981.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981-0-777-026/28